Mineral Development in Ontario North of 50°

Technical Paper #8

Nickel

Dr. H. Strauss
and
Dr. E. T. Willauer

the ROYAL COMMISSION on the NORTHERN ENVIRONMENT

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LAURENTIAN UNIVERSITY

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However, no opinions, positions or recommendations expressed herein should be attributed to the Commission; they are solely those of the authors.

NICKEL

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INTRODUCTION

The outcome of this study is strangely disquieting. Was it the purpose to demonstrate the strength of Canadian nickel production in which especially the people of Sudbury, where this chapter was written, take great pride, the picture which actually unfolded did not confirm the belief. Here are the conclusions in a nutshell:

There is no mineral shortage of nickel in the world for centuries to come, as the metal will become available with the rise of nickel prices whereby the greatest portion of the reserves are held in lateritic form on land and in the sea.

Furthermore, due to huge, planned investment expenditures, especially in countries with lateritic nickel ores, substantial excess capacity will continue to overhang the market until about 1995, ceteris paribus. This excess capacity could find greater utilization if the U.S. were to stockpile this strategic material; unfortunately, this would only be of temporary relief. A better solution, for instance, would be if the United States and its allies were to rearm dramatically for years to come, a policy which would be as controversial as it might be effective; less objectionable would be the third possible alternative solution to the problem: it would come via technological change which would bring to earth the electric vehicle in very large quantities! If these vehicles were to use nickel batteries, the

solution would take the approximate form as circumscribed in the very last footnote!

However, imports of large quantities into the U.S.A. of this metal would conflict with the long-run balance of payment objectives of the United States, forcing that country to open up low-grade land-based deposits and, perhaps, even start seabed mining well before its time. This, in turn, would defeat the argument of utilizing the excess capacity in the world; in particular since it may require substantial public subsidization in the U.S.A.

It also follows that seabed mining of nickel should not be started before the year 1995, nor should laterites and other suppliers make further plans for mine expansion in the meantime. This normative approach only illustrates how urgent and how important it is for Canada and its nickel mining industry to bring the United Nations Conference on the Law of the Sea to a successful and speedy conclusion because the market under the competitive spirit will follow its own course, guided "by the invisible hand" as it has done so far.

The analysis is organized in the following way: Section I presents the metal in its properties, qualities, occurrences as well as its substitutes. Nickel consumption in the United States is at first examined in Section II, followed by consumption in the world and its distribution. World, Canadian and Ontario production are carefully studied in Section III, which also examines

the distribution by main producing countries, the Canadian export structure of nickel and the picture of world refinery capacity.

The most important, though also the longest section, is the fourth. It explores world reserves and their distribution among countries attending to the land-based sulfide and lateritic ores as well as to the more complex problem of the seabed reserves. In addition, it investigates and surveys, as much as possible, the investment activities planned in the reserve-holding countries. Section V addresses itself to the prices of nickel and their future and establishes the future outputs of this important metal as demanded by the world with summary and conclusions to follow.

SECTION I: THE METAL

Properties, Qualities, Occurrence and Substitutes

Nickel is almost white as silver. It is a hard metal but malleable and has conductive properties.[1] One of its chief features is its resistance to oxidization. It can be polished and retains its lustre fairly well.

Nickel occurs in two types of mineral compounds: laterites and sulfides. The laterites are oxides and are generally rich in either aluminum or iron. Nickel counts for but a relatively small percentage of the mineral content. The smelting of laterites is energy-intensive compared to smelting of sulfides. They, however, entail a great public cost in the form of environmental pollution brought about by sulphur dioxide emissions.

There are three types of nickel minerals which eventually will compete against each other: the first is the lateritic type as described above, which is land-based; the second is also of the lateritic variety, but is contained to a small percent in nodules on the bottom of the sea. They are dark-coloured, potato-shaped concretions containing, besides nickel, copper and cobalt, also iron and manganese oxides;[2] the third type consists of the sulfide ores which hold other metals such as copper, gold, silver, PGMs, cobalt, selenium, tellurium, in addition to iron. These ores are land-based, and made Canada

and Russia famous nickel producers. The origin of these deposits, especially the ore in Sudbury, is not entirely certain; however, one theory attributes that particular deposit to the impact of a huge meteorite during the Aphebian Age 1900 million years ago.[3]

Its properties make it useful in a variety of ways. Its corrosion resistance which it bestows on the metal it alloys with in addition to the increase in strength of the alloy has found wide application of nickel alloys in consumer and producer goods. Nickel's specific chemical properties have found useful application in batteries; this is a field which may one day exert an unusual pressure on the available resources; it is also used in dyes, as catalyst and eventually in insecticides.[4]

The following sectors benefit from the uses of nickel:

Chemicals and Allied Products and Petroleum Refining and Allied products;

Fabricated Metal-products;

Aircraft and parts;

Motor Vehicles and Equipment;

Electrical Machinery, Equipment and Supplies;

Household Appliances;

Machinery, Except Electrical;

General Building Construction

Ship and Boat Building

Other Uses (as catalysts and in batteries)

Since nickel is a relatively low-cost material, it is less exposed to substitutes than it serves as a substitute for other

metals. In addition, the metal which would serve as its substitutes may not only be more expensive, but may also be less suitable for the job nickel is performing. In the area of stainless steel, the following metals may serve as substitutes: chromium, manganese, columbium, molybdenum, vanadium and cobalt; nickel may be substituted as a catalyst by the PGMs, cobalt and copper.

If substances can effectively be substituted for nickel, then it is in the general area of corrosion resistance. Not only titanium-clad carbon steel will provide satisfactory services, but plastic coatings, paints, enamel and aluminum may displace nickel-chromium in protective shieldings and trims.[5]

SECTION II: NICKEL CONSUMPTION

Consumption Pattern: U.S.A.

The consumption of nickel in the industrial world may be best exemplified by its use in the United States. Two ways will be explored: one describes the form in which nickel is used - the nickel types - while the other shows the products which utilize these various forms as inputs. The years under consideration are 1971 to 1979.

Nickel Types

Four types of nickel substances are listed: metallic nickel and ferro nickel, oxide, matte and salts. Of these, nickel matte is not used as an input because it is an intermediate product; it is the first main substance of the smelting process and requires the next step of refining before it can be used as an input. Metallic and ferro nickel as well as nickel oxides are such refined inputs.

Nickel salts are inputs of a somewhat higher state of refinement. These salts are normally produced by the chemical industry from oxides and by dissolving metallic nickel in hydrochloric or sulforic acids.

The main inputs of nickel were metallic and ferro nickel. As total consumption of this metal rose from 116,900 to 183,400 metric tons for the years 1971 and 1979 respectively, the share

of metallic and ferro nickel at first went down from 83 percent to 80.0 in the year 1973, after which it rose to almost 91 percent in 1979.

The initial decrease of metallic and ferro nickel is related to a substantial increase in input use of nickel oxides, at least until the year 1974. After this year, nickel oxide lost clearly in significance, ending at 7.4 percent in 1979, as shown in Table 1.[6] Nickel salts registered a steady decline in significance. From 4.0 percent in 1971, they held 1.7 percent in the year 1979. In short, about 91 percent of nickel substances are metallic and ferro nickel which are the most important inputs.

Use Types

Three types of products can be distinguished as the most important users of nickel. They consumed between 83 and 88 percent of the above-mentioned nickel inputs during the period from 1971 to 1979. They are: stainless and other steels, nickel-alloys and electroplating. Of these, the first use type - for stainless and other steels - has been on the rise. From a 39.3 percent share of nickel use, it rose quickly to 46.6 percent in 1974; in 1975, a year in which total U.S. nickel consumption slumped by 30 percent to 132,900 metric tons from 189,100 metric tons in the previous year, the stainless steel share had collapsed to 39.9 percent from the previous 46.6 percent as 58,497 metric tons were used in 1975 compared to 97,026 metric tons in the

Table 1

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Consumption '000 metric tons	116.9	144.5	179.4	189.1	132.9	147.8	140.9	164.0	183.4
Nickel Type	%								
Metal and Ferro Nickel	83.0	83.6	80.0	81.4	85.3	83.2	82.3	86.5	90.9
Oxide	13.0	12.2	16.8	16.1	11.4	13.6	14.5	11.0	7.4
Matte	-	-	-	-	-	-	-	-	-
Salts (partial)	4.0	4.2	3.2	2.5	3.3	3.2	3.2	2.5	1.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Use Type									
Stainless and other steels	39.3	40.8	45.4	46.6	39.9	41.6	45.8	42.5	46.5
Cast Irons	3.2	2.8	2.4	2.5	3.0	2.5	2.4	2.4	1.7
Cu-Ni, Ni-Ag and div. alloys including High Ni-alloys	27.9	23.5	23.3	28.1	34.1	28.0	25.5	26.3	26.4
High Temperature and Electrical Resistance Alloys	6.3	7.7	6.5	6.2	4.8	5.6	7.3	8.7	8.4
Electroplating	16.1	18.2	15.1	12.6	13.1	17.6	14.0	16.5	15.4
Other	7.2	7.0	7.3	4.0	5.1	4.7	5.0	3.6	1.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: ABMS, op. cit., 1975, p. 119, 1979, p. 122.

previous year. In the following years, consumption levels started to recover with a smaller interruption in U.S. nickel consumption in 1977. From then on, nickel demand was up, especially in the stainless and other steel category, holding on to over 46 percent.

The second most important type of use of nickel is in all forms of alloys, which absorbed between 23.3 and 34.1 percent, or an average of 27 percent. Nickel electroplating took up 15.4 percent on the average during these years with no specific trend of change recognizable during these nine years.

There are another three additional nickel uses, which are but of much smaller significance than the previous three. One of these is nickel inputs into high temperature and electrical resistance alloys. They seem to gain in importance over the time period under study. From 6.3 percent in 1971 (4.8 percent in 1975), their input proportion of nickel used rose to over 8.4 percent in the years 1978/79. The other two uses, in cast irons and in 'other uses' such as in money, exhibit significant declines.

In short, the most important uses to which nickel is put are (1) stainless steels and other steel alloys, (2) electroplating, and (3) high temperature and electrical resistance alloys, which is a category by itself. If combined with other alloys, the distribution would see stainless and other steels in first place, followed by (2) alloys now with 34% - and then,

Table 2

World Nickel Consumption[7]

for the Years 1950 to 1979

in '000 metric tons

Year	'000 metric tons	Year	'000 metric tons
1950	158.2	1965	425.4
1951	145.5	1966	460.7
1952	174.0	1967	441.5
1953	182.3	1968	492.0
1954	181.2	1969	504.0
1955	206.9	1970	572.0
1956	230.9	1971	526.7
1957	235.3	1972	580.1
1958	196.4	1973	657.5
1959	249.2	1974	710.7
1960	292.7	1975	577.4
1961	320.8	1976	670.1
1962	318.0	1977	648.7[8)]
1963	344.9	1978	740.5
1964	395.6	1979	798.2

(3) electroplating in third place. This brings out the role played by all nickel alloys.

World Nickel Consumption

The performance of world nickel consumption has been analysed statistically with the results presented above.[9] The past performance could be simply described in the following way: over the thirty years under review, the amount of nickel consumed in the world increased by 305 percent when taking the first and last five year averages, or by 404 percent when comparing the consumption increases between the year 1950 and the year 1979. As shown in Table 2, there has been a persistent rise which can be expected to continue into the future. At the same time, it has to be acknowledged that the rise has not been smooth and continuous. For instance, a substantial slump in world nickel consumption occurred in the year 1958, after a fairly stable rising trend for the previous years. Later on, a continuity reappeared as world consumption rose steadily and persistently without major fluctuations. However, the year 1969 marked a critical turning point. Nickel use shot up from 504,000 metric tons to 572,000 metric tons in 1970; then it receded to 526,000 metric tons in order to just run away to 710,700 metric tons in 1974. It almost collapsed in the next year. The buds of recovery, as shown for the year 1976, were frustrated in 1977, as nickel consumption dropped back to

648,700 metric tons. By 1978, signs of a recovery materialized with 740,500 as the preliminary values. The actual consumption figures amounted to only 701,300 metric tons. Finally, the year 1979 showed some improvement as 782,600 metric tons of nickel were absorbed by the industries in the world.

In short, nickel consumption of the world increased by over 300 percent, but the relatively steady rise was marred after the year 1969 by a substantial ratchet effect.[10]

Consumption by Main Consuming Countries

Having inspected this picture of generally rising nickel consumption in the world, one question follows immediately: Who are the main consuming countries? This problem will be investigated now. Fundamentally, there are three general types of world nickel users; there are those countries whose consumption rises with the general rate of increase of the world as a whole; then, there are other countries whose thirst for nickel exceeds that of the rest of the world. In essence, these are the countries which speed up the general upward trend; and finally, there are those whose demand for nickel declines relatively. These three types of users can be recognized by the relative shares which they hold as world nickel consumers for selected and consecutive years. Countries of the first group simply hold their shares more or less from beginning to end; the countries with a strong consumption demand for nickel display rising shares,

while the less exhilarating consumers display declining shares of nickel consumed in the world.

Let this brief analysis start with the countries of the third category. Two countries stand out as exerting a relatively smaller demand on world nickel than the remainder of the world: the United States and the United Kingdom. As can be seen in Table 3, the United States absorbed 57.3 percent of the world nickel in the year 1950. By 1977, that share had been reduced to 22.5 percent. Two years later, it was back to about 23 percent.[11] In short, the United States is still the world's largest user of the metal, but there are other strong nickel users. It has to be kept in mind that the U.S.A. absorbed about 90,650 metric tons in 1950, 140,800 in 1977 and 183,000 in 1979. In absolute terms, it is still expanding, though slowly.

The United Kingdom, too, displayed a relative decline in significance as a nickel consumer. Its world consumption share declined from 9.9 and 10.2 percent for 1950 and 1955 respectively to 4.7 and 4.5 percent for the years 1977 and 1979. Again, the absolute consumption rose from about 15,700 metric tons in 1950 to 30,500 and 35,000 metric tons for 1977 and 1979 respectively. No question, these two industrial giants who were once the two most important users of the metal in the Western World find themselves under strong competition.

The second category of countries are those whose demand for refined nickel grew at the same rate as the global rate of

Table 3

World Nickel Consumption and Distribution by Main Consuming Countries

for Selected Years between 1950 and 1977

World Consumption of Nickel ('000 metric tons)	1950	1955	1960	1965	1968	1972	1975	1977
	158.2	206.8	290.5	425.4	484.6	580.1	577.4	648.7
Countries	%	%	%	%	%	%	%	%
France	2.6	4.6	6.7	4.9	6.3	5.4	5.5	5.5
West Germany	3.9	5.4	7.9	7.2	7.2	7.4	7.4	8.4
Italy	0.9	1.2	2.3	2.2	3.6	3.6	2.9	3.5
Sweden	1.9	1.9	3.0	3.1	3.3	3.9	3.8	2.7
United Kingdom	9.9	10.2	9.6	8.7	6.8	5.2	4.6	4.7
Other Europe	1.8	1.9	3.0	1.9	2.4	2.8	3.9	3.7
Japan	0.4	1.6	5.1	6.3	10.8	15.1	14.4	15.0
Other Asia	0.0	0.0	0.2	0.2	0.3	0.5	0.8	1.4
Africa	–	0.0	0.1	0.5	0.8	0.6	1.0	0.8
Canada	1.8	2.4	1.8	1.9	1.9	2.1	1.9	1.2
United States	57.3	48.4	33.8	36.7	29.6	27.1	23.0	22.5
Other America	0.1	0.2	0.2	0.4	0.4	0.6	1.5	1.8
Australasia	0.3	0.3	0.8	0.6	0.7	0.6	0.4	0.7
U.S.S.R. and other Countries	19.0	21.8	25.5	25.4	25.8	25.1	28.4	28.1
	99.9	99.9	100.0	100.0	99.9	100.0	100.0	100.0

(310% increase in world consumption)

nickel consumption. Two countries fit this category: Canada and Sweden, the latter at least since 1960. Canada used 1.8 percent of nickel in the world in 1950 which rose slightly to 2.4 percent in 1955. Over the following period until 1975, it remained at about the same level and only later did a small reduction in that share occur. As indicated in Table 3 for the year 1977, that share may have slipped, but by 1979 - not indicated in the Table - it had returned to 1.5 percent. Sweden, in turn, maintained its consumption share after 1960 at a very stable proportion to the rest of the world, ranging between 3 and 4 percent. In 1977, that share had been reduced slightly and by 1979, it was 2.8 percent.

Finally, those countries come into focus which showed rising percentages of world shares of nickel consumption during the period under examination. They are: Japan, West Germany and Italy. The most outstanding performance is given by the unbelievable expansion by the industrial giant of Japan! In the year 1950, its world share was 0.4 percent. Twenty-two years later, 15.1 percent were recorded. Until 1977, its nickel demand grew at the rate of the world as it maintained that proportion at 15.0 percent. In 1979, however, it had moved up to 16.8 percent. Nickel uses in Japan amounted to about 6.3 thousand metric tons in 1950. The year 1979 saw Japan feeding 132 thousand metric tons of nickel into its industrial structure. This simply means that Japan absorbed about twenty times more

of this metal in 1979 than in 1950; economic-industrial development to the highest!

Take Germany, for another example. Its world nickel consumption share stood at 3.9 percent in the year 1950. By 1977, it had moved up to 8.4 percent, as shown in the Table. Two years later, nickel consumption amounted to 9.9 percent of the world total. From an input volume of about 6.15 thousand metric tons in 1950, the application of nickel by Western Germany rose to 77,400 metric tons in 1979; the factor of increase being 12.7 over the 1950 level.

France is another interesting case in point. Its consumption share was 2.6 percent in 1950 when it needed about 4.1 thousand metric tons of the metal. By 1970, its world share stood at 6.1 percent as its industries absorbed 36,100 metric tons of nickel. By 1977 and 1979, the shares stood at 5.5 and 5.0 percent as 35,700 and 38,900 metric tons of nickel found industrial usage in France. Here, a relatively steep initial increase earlier in the period is followed by a somewhat relaxed and consolidated expansion in the demand for nickel, a phenomenon which seems to be germane to industrial development among these outstanding countries.

Besides these particular, highly industrialized countries, the Table refers to regional aggregates of 'other countries'. These other countries of geographical regions which have not been stated explicitly in the breakdown are summarily treated in this analysis of important nickel consumption of the world.

They are the 'other countries' of America, Africa, Asia and Europe. To these have to be added the aggregates of the countries of the Soviet sphere which appear statistically separate only since 1972. It is of utmost significance to realize that these aggregates show a consistently rising world share through the entire period from 1950 to 1977, as set out in Table 3. They are very important sources of the acceleration of world nickel demand. They are, if not already in the process, but at the beginning of their industrial development! These countries will not eternally depend on the imports of the industrial output of the giants. They must develop their own industrial base; that is the essence for the expansion of consumption of nickel now and in the future. Only after they have reached a certain level of industrial production will the rate of acceleration of nickel use diminish!

This point of general retardation of nickel consumption lies very far in the future. It depends on a number of variables, not so much on technological change than perhaps on population increases. If the population prediction of the United Nations is born out, the rate of increase in population of the developing countries will start to slow down only after the year 2020. Between 2080 and 2100, populations of those countries will finally have become stationary.[14] It would, therefore, appear reasonable to suggest that these countries will be bent towards industrialization and development, especially after the

year 2020, and that it is unlikely that there will be a letdown in the future for the demand for nickel, especially as it is still cheaper than the entire gammut of substitutes.

Consider only the larger countries on the road towards industrialization such as all satellite countries[15] in the Soviet sphere of influence, and Brazil and Mexico in the Americas. The latter two increased their consumption of nickel between 1969 and 1979 by roughly nine and eleven times respectively;[16] or take the continent of Africa for an example. It contains the countries screaming for economic and industrial development. Cross over to Asia. There is the giant of China determined as never before to industrialize. Its consumption of nickel, which has historically and statistically been listed between 20,000 and 18,000 metric tons between 1972 and 1979, will not stay that low. Therefore, the acceleration of the growth in nickel demand will come from those countries embarked upon the road leading towards industrial independence. This holds especially for those nations now classified as underdeveloped which, according to the United Nations' projections, will account for 87 percent of the world population by the year 2125.

Consequently, the rising trend in consumption of nickel is attributable to the relatively large usage of the metal by the rapidly developing industrialized countries in the world. From this follows that the concept that the so-called under-developed countries allegedly constitute the general unknown in

the overall picture is wrongly taken; rather they constitute the certainty of sustained expansion of future consumption of nickel as they enter the road towards industrialization, as industrialize they must - and will!

SECTION III: PRODUCTION

Nickel Mine Production: World, Canada and Ontario

The annual mining output of nickel between 1950 and 1979 showed a substantial increase. This is born out in Table 4 below and in Figure 15 of Chapter I.[17] World nickel mines raised their annual output from 149,300 metric tons to 800,600 metric tons in 1977, after which a recession hit the nickel mining industry in the world combined with various strikes and cutbacks. By 1979, output stood at 676,600 metric tons. This does not mean that no fluctuations occurred in that long period until 1977. A first and major dip took place in the year 1958 as production dropped from 303,000 metric tons to 229,000, the time of very serious labour strife in Sudbury. The years 1961-1963, and the years 1969 and 1972 likewise displayed reduced annual outputs than recorded previously. In addition to the true and unbiassed line of expansion of nickel mine production as expressed by the simulated production values in Figure 15, a more simple expression of the dimensions of increase is that the quantity of nickel produced in the world rose from 188,000 metric tons to 736,400 metric tons as the respective averages for the first and last five years of the period under study: world output rose by 291.6 percent.

The performance of the Canadian Nickel Mining Industry is also presented in Table 4. It rose from about 112,200

Table 4

World and Canadian Mine Production of Nickel, and
Canada and Ontario Importance as World Producers
for the Years 1950 - 1979

Production '000 metric tons			Percentage Distribution (percent) of World Mining Output	
Years	World	Canada	Canada	Ontario
1950	149.3[1]	112.2	75.2	75.2
1951	173.1[1]	125.1	72.3	72.3
1952	188.0	127.5	67.8	67.8
1953	204.0	130.3	63.9	63.9
1954	226.0	150.9	66.8	65.4
1955	250.0	158.7	63.5	58.5
1956	260.0	161.9	62.3	58.5
1957	303.0	170.5	56.3	53.1
1958	229.0	126.6	55.3	50.4
1959	290.0	169.2	58.3	54.4
1960	337.0	194.6	57.7	54.3
1961	374.0	211.4	56.5	47.6
1962	367.0	210.7	57.4	41.2
1963	358.0	196.9	55.0	37.8
1964	395.0	207.3	52.5	37.2
1965	458.0	235.1	51.3	37.9
1966	438.0	202.9	46.3	33.2
1967	513.0	225.6	44.0	33.6
1968	546.9	239.8	43.8	33.8
1969	514.7	193.8	37.7	25.9
1970	657.3	277.5	42.2	31.0
1971	680.7	267.0	39.2	28.8
1972	627.1	235.0	37.5	27.4
1973	681.4	249.0	36.6	26.2
1974	748.6	269.1	35.9	27.9
1975	757.0	242.2	32.0	23.7
1976	803.9	240.8	30.0	23.3
1977	800.6	235.4	29.4	22.8
1978	643.7	130.0	20.2	15.1
1979	676.6	131.6	19.5	14.0

[1] adjusted

(Ontario = 81.4% reduction in world share)

metric tons in 1950 to 211,400 metric tons in 1961 and it stayed around this level of annual production for a considerable number of years. Only in 1970 did it climb to a peak of 277,500 metric tons which it never reached again in the years to follow. Cutbacks and strikes saw the Canadian nickel output slump to 130,000 and 131,600 metric tons in the years 1978 and 1979 respectively.

Canada's standing as a world nickel producer is dramatized in the percentage values given in Table 4. At first, 75.2 percent of nickel mined in the world came from this country. This was in the year 1950. Ten years later, this distribution has been reduced to 57.7 percent. Another decade passes and Canada is down to 42.2 percent and in 1977, the last of the years of full production, more than another 12.5 percent have been lopped off from the image that once had seen Canada as the world dominant nickel supplier.

Actually, it was the Province of Ontario, for that matter, which was the sole supplier of the shiny metal. For the first four years, Ontario was the one and only province in Canada which mined nickel. However, this changed as the Province of Manitoba joined this field of mining and it has stayed in it ever since.[18] About 25 percent of all nickel mined in Canada comes from the Province of Manitoba. The Provinces of Quebec, British Columbia and the Yukon made their small and temporary contributions in intermittent years.[19] Therefore, the loss in world stature as a nickel supplier saw Ontario fade from a position

of 75.2 percent to about 23 percent in the normal year of production of 1977; its reduction was much more substantial than that of the country as a whole. Immediately, the question arises as to what happened in the remainder of the nickel mining world.

Main Nickel Producing Countries

Historically, the first main nickel producer in the world was New Caledonia. It began operations in 1875 and it was only in 1905 that Canada became the leading producer.[20] By the year 1935, world output amounted to 76,000 metric tons of nickel content in ores, with Canada producing 62,800 metric tons or 82.63 percent. New Caledonia, at that time, contributed 8,200 metric tons or 10.8 percent as the next closest competitor to Canada. Burma, Norway, Greece and the United States supplied the remainder. By 1977, the picture had changed substantially. Instead of only six nickel mining countries, the world counted 22 sources of supply. Output had risen to 800,600 metric tons or by a factor of 10.5. Canada's contribution, however, rose only by a factor of 3.75 and it was in this fashion that its stature declined from 82.6 percent in 1938, to 75.2 percent in 1950 and to 29.4 percent in 1977. New Caledonia's output stood at 115,000 metric tons. This marks an increase by a factor of 14 and it was thus able to maintain its world share as it held in 1935, even if, in 1970, its mining output was 21.1 percent of the world total. This can be seen in Table 5.

Table 5

World Nickel Ore Production and Percentage Distribution of Main Producing Countries for Selected Years between 1955 and 1979 ('000 metric tons)

	1955	1960	1965	1970	1975	1979
World Output	250	337	458	627.1	757	676.6
Albania	-	0.7	0.8	0.8	0.9	1.3
Australia	-	-	-	2.7	6.5	10.9
Botswana	-	-	-	-	0.9	2.4
Brazil	0.0	0.0	0.2	0.5	0.4	0.6
Canada	63.5	57.7	51.3	42.2	32.0	19.4
Cuba	5.5	3.8	6.2	5.6	4.8	5.5
Dominican Rep.	-	-	-	-	3.5	3.7
Finland	-	0.7	0.9	1.0	0.7	0.9
Greece	-	-	-	1.3	2.0	3.0
Indonesia	-	0.1	0.8	2.4	2.5	5.3
New Caledonia	9.9	15.8	17.7	21.1	17.5	10.9
Phillipines	-	-	-	0.0	1.2	5.3
South Africa	0.9	0.9	0.7	1.7	2.7	3.3
Zimbabwe	-	0.0	0.2	1.7	1.3	2.4
U.S.S.R.	17.6	15.7	17.5	15.8	20.1	22.5
U.S.A.	1.8	4.0	3.4	2.6	2.0	1.9
	99.2	99.4	99.7	99.4	98.0	99.3

Source: United Nations, _Statistical Yearbooks_; New York, ABMS, _Non-ferrous Metal Data, 1979_, New York, N.Y.

In 1975, a more normal year of production, the U.S.S.R. had become the world's second largest producer, while New Caledonia had fallen into third position. In the same year, Australia had very suddenly become a significant producer in the world, which, by 1979 standards, made it draw even with New Caledonia.

Cuba is another producer of world significance. Already, in 1955, it held 5.5 percent of the world total and it succeeded in maintaining its world share of nickel mining output. Simultaneously, in 1979, Indonesia and the Philippines held equal shares with Cuba, to which could be added the combined total production of South Africa and Botswana. Next in line is the Dominican Republic, Greece and Zimbabwe. Other countries such as Albania, the United States, Finland and Brazil are in the third line of producers, not to name the remaining six which may, one day, be quite significant suppliers, a point to be discussed later.

In short, Canada is still the world's largest producer, but the strength and the number of competitors is mounting systematically.

Canadian Nickel Trade

Understandably, Canada is very actively involved in the international nickel trade. It is an exporter in:

1 Nickel ores and concentrates,

2 nickel oxides, and

3 nickel and nickel alloy scrap;

Canada is an exporter and importer of:

4 nickel anodes, cathodes, ingots and rods; and

5 nickel and alloy fabricated materials not elsewhere specified;

Canada imports the following nickel products:

6 Nickel in ores, concentrates and scrap,

7 nickel alloy ingots, blocks, rods,

8 nickel and alloy plate sheet and strips, and

9 nickel and nickel alloy pipe and tubing.

The overall picture of Canadian trade in nickel products has been set out in Table 6 which gives the volumes in metric tons for the years 1977 to 1979 and the distribution by type of product. In comparison to the Canadian mining output it is clear, at least from the figures of 1977, that a very large percent of the mined product finds its way into international markets. When Canada produced 235,400 metric tons of nickel ore (nickel content) in that year, the export figure for that calendar year stood at 206,730 metric tons. It simply means that, roughly speaking, 87 percent of Canadian nickel mined is exported. If imports are taken into account, 165,953 metric tons were the net nickel exports, or, 70 percent of all nickel mined in Canada. In the following years, exports exceeded production which was smaller

Table 6

Canadian Nickel Export and Import Structure for the Years 1977-1979

By Commodity Items

	Commodity	EXPORTS			IMPORTS		
	Item	1979	1978	1977	1979	1978	1977
	volume	158,864	189,698	206,730	32,443	40,864	40,777
Nickel Ores and Concentrates	255-20	26.90	20.60	38.96	-	-	-
Nickel in Oxide	255-30	10.82	14.65	16.93	-	-	-
Nickel and Nickel Alloy Scrap	255-40	1.50	1.22	1.05	-	-	-
Nickel in Ores, Concentrates and Scrap	255-99	-	-	-	65.27	78.01	80.48
Nickel Anodes, Cathodes, Ingots and Rods	454-15	53.32	55.70	36.10	10.22	3.53	5.90
Nickel Alloy Ingots, Blocks, Rods, etc.	454-69	-	-	-	3.20	6.30	1.43
Nickel & Alloy Plate Sheet and Strips	454-76	-	-	-	10.29	6.73	5.98
Nickel & Nickel Alloy Pipe & Tubing	454-85	-	-	-	6.20	3.78	4.50
Nickel & Alloy Fabricated Mat. N.E.S.	454-99	7.46	7.83	6.95	4.81	1.64	1.72
		100.00	100.00	99.99	99.99	99.99	100.01

due to the cutbacks and the labour strikes in the industry while the exports fed on the huge inventories which had accumulated over previous years.

In the export field, nickel ores and concentrates took up 38.96 percent of all shipped nickel quantities which went mainly to the nickel refineries of INCO in Clydach, Wales, and to the Falconbridge refinery in Kristiansand, Norway. This can be seen in Table A1 in the Appendix to this chapter.

All other exports of nickel materials were at a higher stage of refinement with a larger domestic value-added marking the products.

The second largest items in this field are nickel anodes, cathodes, ingots and rods. They amounted to 36.1 percent in that particular year, with the United States, the countries of the E.E.C. and other countries as the main customers. This has been brought out explicitly in Table A5 in the Appendix. Mark also that during the years of reduced production in Canada, nickel ores and concentrate exports were in second place, while the exports of refined nickel products were in first place with between 53 and 55 percent of total exports.

The third most important nickel export items are the oxides. They account for about 14 and 16 percent (1979: 10.82 percent) of all nickel exports. Again, the United States, the countries of the E.E.C. and other countries were our main customers (see Table A2 of the Appendix). The last of the important

export items refers to nickel and alloy fabricated materials. They constituted about 7 percent of our nickel exports. Here, the United States were the most important customer, always taking 80 percent and above as demonstrated in Table A9 of the Appendix. Other European countries, such as the United Kingdom in 1977 and 1978 and the Benelux countries in 1979 accounted for up to 8 percent of this specific commodity item.

On the import side, it has to be realized that this sector of the nickel trade is much smaller than the exports. The first item in Table 6 is also the most important one: nickel in ores, concentrates and scrap. For those three years, between 65 and 80 percent of all nickel imports were taken up by this item. The main source of these supplies were Australia, followed by the United Kingdom and then by United States. This means that considerable amounts of raw materials from Australia came into Canada for further refining such that our mining industry may have benefitted from this type of transactions, when seen through the glasses of the domestic value-added approach.

Two commodity items are in second place of importance as concerns the import of nickel products. They are nickel anodes, cathodes, ingots and rods as one, and nickel and alloy plate sheet and strips as the other. Both accounted for about 5.9 percent in 1977 and for 10.3 percent in 1979. The larger

share of the first item came from Norway while the remainder originated in the United States. Both items could be considered as reimports. As to nickel alloy plate sheet and strips, the United States and West Germany were the main sources of origin, with the United States the most important one. The details of these two items have been set out in Tables A5 and A7 of the said Appendix.

Three import items may be treated together: Nickel alloy pipes and tubings (Table A8), nickel alloy ingots, blocks and rods (Table A5) and nickel and alloy fabricated materials (Table A9). Two countries again stand out as the most important suppliers in the fields: The United States supplying always over 50 percent of these imported quantities per item except for 1977, when Canada imported 87 percent of nickel anodes, etc., from Norway. Again, reimports may be subsumed, because the Canadian trade statistics do not specify reimports as being beyond the control of Statistics Canada. However, since Falconbridge refines its nickel matte in Kristiansand, the respective products may understandably reappear as imports into this country. In turn, it is also apparent that the reimported nickel in anode-form, etc. may then, again register as an export - reexport that is - when entered in the same commodity item, unless reexports and reimports have already been taken into account by the basic statistical assessment operations in Statistics Canada. If

this were the case, then the imports would refer to additional nickel which was toll-refined in Kristiansand for Falconbridge customers in other countries which were the suppliers of the ores (e.g. Amax from Alaska).

In short, Canada is a significant net exporter of nickel products, shipping nickel mainly in refined and ore forms. In addition, Canada smelts and refines ores coming from other countries, especially from Australia. At worst, 70 percent of our mined nickel finds its way into foreign countries.

Smelting and Refining Capacities[21]

There is a certain difficulty in exactly assessing the smelting and refinery capacities of the world. For one, the statistics are not complete as, for instance, China has not been included in the following Table 7. Also, for certain countries, capacities have not been specified although they are known to exist, however small they may be. For another, the capacities to smelt and to refine nickel have been lumped together such that one does not recognize the actual capacity to produce refined nickel on an annual basis. That is why one cannot sum the capacities of all countries to arrive at a global capacity figure. This is impractical since it would involve a double-counting of nickel raw materials for smelting and refining.

Table 7

Nickel Smelting and Refining Capacity

by

Main Producing Countries

for the Years 1956 - 1957 and 1979
(net tons)

Country	1956	1957	1979	% Change $(\frac{1979}{1957})$
Australia	-.-	-.-	84 800	-.-
Canada	178 500	179 000	296 300	50.4
Dominican Republic	-.-	-.-	33 000	-.-
Finland	-.-	small	7 700	-.-
Greece	-.-	-.-	16 500	-.-
New Caledonia	15 000	12 000	77 000	541.7
Philippines	-.-	-.-	35 200	-.-
South Africa	-.-	small	41 800	-.-
Botswana	-.-	-.-	18 700	-.-
U.S.A.	8 000	9 000	54 000	500
Cuba	15 000	15 000	44 000	193.3
Japan	2 500	14 000	221 000	1478.6
U.S.S.R.	45 000	48 000	132 000	175.5
France	10 000	11 000	16 000	45.5
Guatamala	-.-	-.-	14 000	-.-
Indonesia	-.-	-.-	50 000	-.-
Norway	15 000	20 000	48 000	140
U.K.	25 000	25 000	47 000	88
Germany-West	11 000	5 000	-.-	-.-

Source: American Metal Market, Metal Statistics, 1956, 1957, 1979. A Fairchild Publication, New York, N.Y.

Nonetheless, the information imparted from Table 7 is both highly informative and interesting. It provides an insight into the nickel activities of a number of countries by the mere capital formation that has taken place over the time period 1956/57 to 1979.

The most outstanding example is that of Japan. Between 1957 and 1979, capital installations for the processing of nickel in Japan rose from 14,000 to 221,000 net tons, which is a substantial increase of 1479 percent or by a factor of 15.8. Were one to use the figures for 1956, that increase would show a factor of 88.4, meaning that Japan increased the nickel processing capacity 88.4 times during this period. This is the clearest indication of the significance which the industrial strategists of Japan attached, very early, to the domestic processing of nickel instead of importing the refined product from a country such as Canada. From this point of view, Japan will always and gladly import the unprocessed and semi-processed raw material and one will find the import of refined nickel into Japan to be the exception rather than the rule.

Canada, which has the largest capital investment in this area, displayed only a relatively small increase during this period of time. This 50 percent increase in a country known for its nickel resources compares poorly with that of Japan,

which has no domestic nickel mines. In addition, it is difficult to determine how much Japan has imported in the form of ores, concentrates or matte in recent years from this country.[22]

The third largest processor of nickel is the Soviet Union. Its capital formation for the processing of this metal has been substantial and consistent. From 45,000 and 48,000 net tons of smelting-refining capacity, the U.S.S.R. has arrived at 132,000 net tons in the year 1979. Even if these figures are estimates only, they, nonetheless, leave quite a realistic impression of what has happened in the past in the U.S.S.R. This is quite in accordance with the output figures presented in Table 5. Amazingly enough, the country with the next largest capital formation for nickel processing is not New Caledonia, which increased its capital stock from 12,000 to 77,000 net tons, or by 541.7 percent over the period under study, but Australia. It recorded 84,800 net tons for the year 1979. This means that this country, too, is breaking into the nickel market.[23]

The United States, Indonesia, the Philippines and Norway are other countries showing substantial formation of capital in the processing of nickel substances whereby the increases in the United States and Norway - Falconbridge that is - are very impressive.[24]

Indonesia, listed with 50,000 tons, displayed the importance of the smelting capacities in its nickel operations with a number of companies involved. INCO's smelters, with a planned capacity of 17,000 tonnes, accounts for a major share of this nickel capital stock of this country.[25]

South Africa and Botswana[26] have a combined nickel processing capital which appears to exceed that of Cuba. The latter country has substantial ties with the U.S.S.R. for the development of its nickel resources. Or, consider the Dominican Republic. There, it is the subsidiary arm of a company of Falconbridge - Falconbridge Dominicana C. Por A - which is instrumental in nickel mining and processing on that island country. Let your view wander over the map to Guatamala. Again, it is INCO which has established a nickel smelter operation under the subsidiary of Exmibal in this central American country.

The last of the major nickel processing countries is Greece. This country's nickel operations are run by LARCO - Société Minière et Metallurgique de Larymna, S.A. which is located at Larymna.

At the end of the list are two countries, France and Finland. The French refinery processes 75 percent nickel matte from New Caledonia and has a capacity to produce 16,000 metric tons of nickel and about 400 metric tons of cobalt annually.

It is located at LeHavre-Sandouville and is again in operation after it was ravaged by a fire on February 24, 1979.[27] The smallest of all listed operations is located in Harjavalta. This Finnish operation is owned by the world-famous firm of Outokumpu Oy. It has a capacity of 7,700 tons which is still small by any comparison to the other producers. In this sense, it may not have increased significantly its processing facilities in Finland over the time under consideration.

In short, five countries have substantial nickel processing facilities: they are Canada, Japan, the U.S.S.R., Australia and New Caledonia. Other countries, such as Indonesia, the Philippines, Norway, Cuba and South Africa and Botswana, as well as the Dominican Republic, may be considered as countries with substantial nickel processing facilities. In total, no country can match the phenomenal capital formation which has taken place in the country of Japan.

SECTION IV: NICKEL RESERVES AND ALTERNATIVE SUPPLIERS

This section is an attempt to appraise in a general, though critical way, the nickel ore reserves on land and in the sea and to examine the present and planned investment activities by the main holders of these reserves.

Nickel Reserves

Land-Based Nickel Reserves

An exact determination of nickel reserves is extremely difficult if not impossible. This is so because the official information is inadequate and this may hold true on a world-wide bases. Ore reserves are also a function of the distribution of quantities and grades of minerals, of their cost of mining and, eventually, of the market price which is subject to change. In addition, neither the firms, as the resource holders, nor the governments, such as that of the Soviet Union, do clearly report the reserves they actually have. Canada is no exception! Authorities such as the Ministry of Energy, Mines and Resources of Canada, can only publish the information which they receive from the companies. For instance, the following reserve figures were given recently

by this Ministry:

Nickel Reserves for the Years 1975-1980:[28]

	metric tons
1975	7,268,000
1976	7,266,000
1977	7,326,000
1978	7,389,000
1979	7,070,000
1980	7,179,000

These figures for Canada just spell out the delineated ore reserves which the various companies have surveyed and which they report more or less uniformly to the governments. If one considers that between 1975 and 1979 Canada extracted 979,200 metric tons of nickel, it does come as a surprise to the uninitiated that the reserves are not down to 6,288,800 where they should be in good 'Dennis Meadow' fashion, but that we are down only by 100,000 metric tons, which means that Canada has gained about another 880,000 metric tons while travelling that road!

Rising nickel prices have transformed marginal mineral deposits into ores, while the active mining companies revised their delineated potential annually by adding (a) new delineations to the previous ones. This does not mean that they were not aware of these deposits, but it has been the custom to report delineations at the discretion of the companies; (b) new orebodies may have been discovered adjacent to existing orebodies under exploitation, and (c) new and separate discoveries

may have occurred. All these factors add to the enlargements of potential ore reserves of a country.[29]

Thus, if one is to be critical of the reported quantities, so one has to be critical of the summary statements of the average grades reported by governments. No doubt, much depends on the views taken by the reporting firms and assessment practices adopted. Consequently, the values reported in the above-mentioned publication is only useful in demonstrating that there is more in the ground than hits the general eye of the casual observer. For this reason, other sources are more suitable to the task before us and, as done in the other chapters of this report, three main references are utilized, although even these are subject to similar upward adjustment over time.

According to Fleming, in the first kilometer of the outer crust of the continental landmass, geological estimates assess the total quantity of contained nickel at 32,000,000,000,000 tons at 0.008 percent.[30] If there is that much nickel in the earth, where then does it come from?

On this planet earth, it has been observed that the earth's crust, which goes much deeper than the first 1,000 meters, has an average occurrence of nickel of 90 ppm. If the drill is put deeper into the next layer, it is called the mantle of the earth with a thickness of 2,896.8 kilometers

or 1,800 miles - then the average nickel grade in that mass is 0.1 to 0.3 percent nickel. If, finally, the innermost part of our planet is analyzed, one may be surprised to find a nickel content of 7 percent.[31] That is why, in essence, there is no mineral shortage of nickel on this particular spaceship. However, when it comes to the economic side of extracting nickel, one needs accessible ores and these are the reserves and their estimates to which we may turn now.

Table 8 provides three reserve estimates and their distributions among the resource-holding countries. There are two short-run estimates (1) + (2) and one long-run set of figures (3) including their distribution. The first of the two short-run nickel reserves is based on the Table provided by Duncan R. Derry.[32] Although these are 1979 estimates, the values differ in a variety of forms from the second set of short-run figures envisaged by the U.S.B.M. and recorded by Corrick.[33] Duncan R. Derry is more pessimistic in his reserve outlook by allocating to the U.S.S.R. only 2,700,000 metric tons of reserves in contrast to Corrick who allocates 5,171,000 metric tons to the U.S.S.R.

With respect to Canada, the outlook of both estimates is more favourable than the figures given by the Canadian Ministry of Energy, Mines and Resources as referred to above.[34] In this case, however, it is Derry who appears as pessimist,

TABLE 8

WORLD NICKEL RESOURCES AND DISTRIBUTION BY COUNTRY for 1975 and 1979

(in 1000 of tons of nickel content)

	Short-run				Long-run		
	(1)	%	(2)	%	(3)	%	*)
USSR	2,700	4.0	5,171.0	9.58	9,072.9	8.12	S/L
Canada	7,800	11.56	8,709.1	16.13	16,238.9	14.54	S
Australia	5,100	7.56	4,989.6	9.24	7,257.6	6.50	S/L
New Caledonia	13,600	20.15	23,587.2	43.70	24,494.4	21.93	L
Cuba	3,100	4.59	3,084.5	5.71	18,144.0	16.25	L
Indonesia	7,100	10.52	4,536.0	8.40	5,533.9	4.96	L
Philippines	5,200	7.70	1,088.6	2.02	7,257.6	6.50	L
South Africa	5,700	8.44	---	-			S
Greece	2,900	4.30	---	-			L
Botswana	400	0.59	---	-			S
Dominican Republic	1,000	1.48	907.2	1.68	997.9	0.89	L
U.S.A.	2,500	3.70	181.4	0.34	13,789.4	12.35	S/L
Zimbabwe	500	0.74	---				S
China (Mainland)	6,400	9.48	---				S
Albania	100	0.15	---				S
Other	3,400	5.04	---				
Columbia			453.6	0.85	907.2	0.81	L
Guatemala			544.3	1.01	1,360.8	1.22	L
Puerto Rico			---	-	816.5	0.73	L
Other			---	-	1,270.1	1.14	
Africa			725.8	1.34	4,536	4.06	
	67,500	100.00	53,977.5	100.00	111,676.3	100.00	

*) S = Sulfide ores, L = Lateritic ores.

since the U.S.B.M. envisaged an ore reserve for Canada which was 900,000 metric tons larger than the former's and which was already much larger than the 7,268,000 metric tons recorded by the Federal Government Ministry of Energy, Mines and Resources. As regards Australia, both allocate a very similar amount to that country which is almost identical to the annual share of mineral output as stated in Table 5 above.

A 10 million metric ton difference is noticeable between the two estimates for New Caledonia. Derry assigns 20.15 percent to New Caledonia as its share in the world's nickel reserves, whereas the U.S.B.M. follows the conventional approach of granting this huge nickel island a world reserve total of 43.70 percent.

There does not seem to be any disagreement with respect to Cuba's nickel reserves (5.0 approximately as part of the world's total). However, in regard to the nickel reserves of Indonesia, Derry thinks that Indonesia has 3,800,000 metric tons more than Corrick can report. This difference may be explained through the recent discoveries made on the various islands of Indonesia. The same holds for the Philippines, which has come more and more into the 'nickel limelight' in recent years.

It is likewise amazing that Africa ranked so low on the picture of the U.S.B.M. as only 725,800 metric tons of nickel were considered the continent's short-run reserves. Derry would allow for 6,600,000 metric tons of nickel in Africa with

5,700,000 in South Africa, 400,000 in Botswana and 500,000 in Zimbabwe. The U.S.B.M. has provided only for 725,800 for the whole of Africa in the short run and 4,536,000 in the long run. This means that considerable discoveries must have been made in between the years 1974 and 1979.

According to Derry, there is no question that Greece is a country the reserves of which have to be counted as significant; this is not the case for the U.S.B.M. which has excluded Greece from the specific tabulation.

Even when it comes to the assessment of the reserves of the United States itself, the Derry assessment is more favourable in the short run by allowing the U.S.A. a much larger share of the world's total than the U.S.B.M. can provide. There may be a number of explanations for this discrepancy, one of which is that the firms reporting to the U.S. government authorities are responding in a similar way as they do in Canada. Another, and more plausible reason, is that certain nickeliferous deposits have become mineable in the meantime. The point here is that originally, the 181,400 metric tons referred simply to the lateritic nickel ores in Riddle, Oregon which are under exploitation by the Hanna Mining Corporation. However, there are other nickeliferous lateritic deposits in California, Oregon and Washington, which at the time of the U.S.B.M. assessment, were uneconomic for extraction. In the meantime, however, the price of nickel has doubled from the

$ U.S. 1.7675/lb recorded for the year 1974. (Current dollars) Therefore, certain deposits became minable by 1979, which were uneconomic at the earlier date - and therefore, part of the long-run reserves.

Another country of interest is China, about which very scant information is available. Derry places China's nickel reserves at 6,400,000 metric tons, an estimate which another source sets at about 7,000,000.[35] Regardless of which of the two is correct, essentially this estimate places 10 percent of the world short-run nickel reserves at the disposal of this great Asian country. On account of the change in nickel prices and the inclusion of China, the Duncan R. Derry estimate would appear to be a more acceptable figure now than the somewhat outdated value of the U.S.B.M. If adjustments are made for the differences between Canada and the U.S.S.R., the estimate for the world would be around the 70,000,000 (plus) metric tons figure.

From the long-run point of view, which permits leaner reserves to be included, the total reserves estimated by U.S.B.M. in 1974 stood at 111,676,300 metric tons. The distribution has been set out in Table 8, column (3). According to this table, the U.S.S.R. has substantially larger nickel ore reserves amounting to over 9 million metric tons. Canada too comes better into the foreground. Here, the reserves of the Thompson Nickel Belt stretch 100 miles long and about 5 miles wide, provides for additional reserves, the total of

which is not publicly known, but which has to be considerable! The occurrences are not of a continuous form but consist of a large number of separate and dispersed orebodies. Consequently, Canadian ore reserve of 16,238,900 million tons is much closer to what geologists may figure as reasonable nickel resources of this country. From the Sudbury point of view, even this amount may still be an understatement!

Australia can be considered an even more important future nickel supplier. This is due to additional low-grade nickel reserves and there is no doubt that Australia will remain a strong nickel supplier for a long time to come.

New Caledonia will remain the world's largest known nickel source for a very long time. It is also of interest that the long-and short-run reserves do not differ by very much. This means that the ore is of a relatively uniform grade and has been delineated more completely than has been possible for other countries.

The greatest surprise is Cuba. It is not generally known that Cuba, after New Caledonia, is,from the long-run point of view, the second largest source of nickel in the world. Cuba, therefore, will play a very important role in the international nickel market!

Indonesia and the Philippines are two countries whose long-run reserves are substantial as per Table 8, although

the U.S.B.M.'s estimate appears to be smaller in the long-run than Derry's short-run, a point raised before. Suffice it to say that the reserves of the Philippines and of Indonesia should be subject to substantial revisions as time goes on.

The U.S.B.M. statistics for that year - 1974 - has provided little for the continent of Africa. Therefore, from the point of the short-run view alone, the total has to be much larger than the 4,536,000 metric tons provided in Table 8. This holds even true for the Dominican Republic, where the short-run (Derry) reserves exceed the estimated U.S.B.M. total.

Of special interest is the adjustment made for the United States. Its reserves are 13,789,400 metric tons of nickel over the long run. This means that other huge nickel reserves are located in the United States. There is a large low-grade sulfide occurrence in Duluth known as the gabbro deposits of Minnesota, which is close to the famous Mesabi Range. This orebody covers an area of 50 x 3 miles and contains 4 billion metric tons of ores. The grades are at least 0.5 percent copper and 0.15 percent nickel. AMAX, in connection with the Bear Creek Mining Company, is very active in the area[37] while INCO, which still today has mining leases in the area,[38] once extracted a 10,000 ton sample which was processed in the Canadian facilities. At that time (in 1974)

the Company announced that it was not yet interested in opening up the leased deposits. A target date of 1980 had been mentioned[39] but considering the convulsions the nickel industry went through at the end of the 1970s, nothing has materialized in this respect.

Another country for which long-run reserves have been omitted is China. As stated above, the magnitude would amount to about 7,000,000 metric tons of nickel. If added to the total, the estimated world reserves would be in the neighbourhood of 120,000,000 metric tons, marking a rough adjustment to the 111,676,300 quoted by the U.S.B.M. and based on information from the Geological Survey of the U.S.

At this juncture, it is important to separate two types of deposits among the total stated so far: Sulfides and laterites. Following Derry, the world reserves consist to 20 percent of sulfides and to 80 of laterites. Actually, this is not born out in Table 8. Admittedly, there is a preponderance of laterite deposits, but the competitive position of the sulfides is not that small as indicated. According to the figure, and considering that the Duluth gabbro (sulfides) amount to 10 percent of the world total, more appropriate figures would be 40 percent sulfides and 60 percent laterites. This is an approximation of the composition of the land-based nickel reserves. However, should the general

estimate for the laterites as exist in the Pacific and Carribbean be more substantial perimeters than presently observed, then corresponding adjustments could be made. This means that, in the context of this analysis, the land-based laterites may account for a minimum of 60 percent and a maximum of 80 percent of all nickel ores in the world.

As pointed out in Section I, the difference between the two is that the laterites are oxides requiring considerable energy for smelting and refining. The rise in energy cost ever since the early 1970s has removed the laterites from their highly advantageous, competitive position which they held previously, versus the sulfides. Nonetheless, countries are very active in finding cost-saving methods of refining these laterites, either by substitute energy sources, through other metallurgical processes such as leaching, or by improving efficiency!!

The rising energy cost has been the benefit of processing sulfide ores. Without the oil price increase by OPEC - the international oil cartel - the conditions in the Ontario nickel mining industry could be worse than what they have been in recent years, albeit it is fair to say that the recessionary developments which affected world market conditions so adversely late in the 1970s were engendered by the same rise in energy costs. Besides the preferred position of the

sulfides which absorb about 10 percent in energy out of operating expenses in contrast with the laterites where the proportions of between 40 and 60 percent go against energy. Nonetheless, it nas to be recognized - and this is of extreme importance - that even under these restraining conditions, the laterites of New Caledonia, Cuba, Indonesia, Philippines and the Dominican Republic have been successful in competing against the sulfides. Otherwise, these countries would not have made the inroads into the nickel market as they have done; and they will continue in this direction very strongly, as will be shown below.

Sea-bed Nickel Reserves

The sea-bed nodules, or manganese nodules as they are called, are widely distributed through both freshwater and seawater environments. However, those potentially exploitable for their nickel, copper, cobalt and manganese content are found in significant quantities on the seafloor at depths exceeding 3,000 metres. They are black or brownish in colour depending on their iron content. They are normally one to four inches thick and are preferred in that size because they are usually of high mineral grade.

The qualities of the nodules on the floors of the various oceans are not of uniform grade. They differ substantially between the Pacific and the Atlantic Oceans, as presented in Table 9. It is therefore clear that the nodules of the Pacific

TABLE 9

AVERAGE COMPOSITION
OF AIR DRY MANGANESE NODULES
(percentage by Weight)

	Pacific Ocean	Atlantic Ocean
Mn	29.8	15.7
Fe	4.8	15.5
Co	0.2	0.41
Ni	1.36	0.59
Cu	1.2	0.14
Zn	0.12	0.05
Pb	0.05	0.15
Al_2O_3	5.7	4.9
SiO_2	13.0	2.9
Ca	1.47	7.32
Mg	1.7	1.7
Si	0.07	0.19
Ba	0.61	0.52
K	0.79	0.31
Na	2.6	2.3
P	0.05	0.15
Ti	0.44	0.34
Mo	0.05	0.05
V	0.05	0.07
H_2O	16.2	15.6
L.O.I.*	22.0	23.8

Source: J.P. Drolet., Loc. cit. p. 30 based on an article in metall gesellschaft AG., Review of Activities, Edition 18, 1975.

* L.O.I.: Loss on ignition

are of greater economic interest since they contain much larger percentages of manganese, nickel, copper and zinc than those found in the Atlantic Ocean. There, the nodules are much more abundant in iron at the expense of mainly manganese, which has a content of only 15.7 percent in the Atlantic Ocean versus 29.8 percent in the Pacific Ocean. On account of these quality differences, it is clear that the Pacific nodules are preferred candidates for sea-bed mining of nickel. However, this is not sufficient. A considerable importance is attached to the density of the occurrence which has to be at least 10 kg of wet nodules per square metre to be considered a potential resource; deposits with half that amount would qualify simply as resource.

Regardless of the cost of mining of these sea-bed nodules one point is clear: these resources fall right into the category of 'short-run reserves' as they are comparable, in nickel content, to the other land-based laterites, to which they chemically belong. Therefore, there is an undeniable three-way competition among the land-based sulfides, land-based laterites and sea-bed nodules with the various winners depending on the grades, capital and operating cost of recovery and prices. It is also clear that deposits of the Duluth gabbro type are out of the range of feasibility if the grade is as low as stated and barring no technological breakthroughs recorded in both mining and refining technology, which could

outweigh the low grade of that and similar mineralizations. References should be quoted to illustrate the magnitude of the long-run nodule reserves on the one side and - given the nickel prices and the market conditions of the late 1970s and early 1980s - the short-run reserves on the other.

Taking the largest view possible, Corrick writes:

> «Deposits of possible economic significance have been delineated by traversing favourable areas with television cameras. Some estimates indicate over 1.5 trillion tons of nodules occurring on the ocean floor at depths ranging from 100 to 10,000 feet. Reportedly, the nodules are continually forming at a rate of 10 million tons per year.»[41]

Evidently, this is a huge mineral reserve which is theoretically non-depleting. Nonetheless, this is a meaningless statement because once nodules have been removed, it will take hundreds of thousands of years to replenish the mined sea stock.[42] Translated into nickel content at 1.1059 percent (Pacific:Atlantic assumed 2:1) the nickel resting on the bottom of the seas would amount to 16,590,000,000 metric tons.

Another expert in the mineral field, M.G. Fleming, in the Tenth Sir Julius Wernher Memorial Lecture before the Tenth International Mineral Processing Congress described the mineral potential of the seas in the following way:

> «...in a large area of the central Pacific Ocean, the sea-bed is covered with nodules that are estimated to contain 2,400,000,000 tons of copper and cobalt, 3,600,000,000 tons of nickel and 96,000,000,000 tons of manganese, much of which is now considered to be potentially recoverable.»[43]

This statement is, of course, very cautious since it speaks of potentially recoverable. Mr. Jean-Paul Drolet, unquestionably an eminent Canadian expert, is understandably much more guarded. He takes into consideration other real cost factors. He refers to the cost of retrieval, transportation and processing. They have to cover the difficulty of the terrain on the ocean floor which is not flat and without features, but full of ranges of rolling hills, faults and various other geography. The reader may easily obtain an impression of these conditions by consulting generally available maps of the ocean floor published by the National Geographic Magazine.[44] Especially, the area of greatest known concentration of these nodules are the Clarion Fracture Zone and the Clipperton Fracture Zone in the Pacific Ocean. These are characteristic of such difficulties. This means that one has to be selective in the determination of the recovery areas to start with. In addition, seafaring is another business and to be a sea-bed miner has many attributes of risk above water which may be similar to those encountered underground. Mining will occur from ships which are not easily anchored to the sea bottom as floating oil rigs. This exposes the ships to all the dangers and vicissitudes of heavy seas, wind and weather. To expect a continuous mining operation as can be entertained on land is equivalent to not knowing what the sea is like. If one adds the risk to men and equipment of

seaquakes for which the Pacific Ocean is more famous than any other of the seven seas, the real cost will be huge and production potential may be quite limited. However, it is admitted that these nodules represent a challenge to mankind, especially in the light of those adverse conditions surrounding their recovery!

When considering these factors, the reserve estimate becomes more manageable. As Mr. Drolet writes:

> According to the most recent estimates that take into account the above-mentioned factors,[44] the amount of nickel that might be recoverable from nodules in the northeast equitorial Pacific Ocean* alone is estimated to be in the order of 20 million tons of metal, which is equivalent to about one quarter of current land-based known reserves of the world.**
>
> ---
>
> *Presently this region is attracting the main interest. It is a 3-million square kilometres zone lying south of Hawaii and west of Mexico between the Clipperton and Clarion fracture zone located between 7°N and 15°N and between 120°W and 150°W.[45]
>
> (**refers to the U.S.B.M. and the Canadian official reserve estimates)

Even if the volume of exploitable nodules is larger than this study is inclined to assume, the figures for the additional nickel reserves in the seabed may be summed up in the following fashion.

The gross total in the secular sense - for millenia to come - may be put at 15,050,000,000 metric tons. This is

secular reserve II. The very long-run reserves - secular I - would be 3,266,000,000 metric tons, while the definite short-run reserves would stand at 23,475,000 metric tons. This last figure is obtained after two adjustments: one is the computation into metric tons, while the other stems from a short-run growth allowance similar to that shown between the 70,000,000 metric tons of short-run land-based reserves established versus the 53,977,000 metric tons observed in column (2) of Table 8.

The following breakdown sums up the reserve story:

(metric tons)

	Land-Based	Sea-Bed	Total
short-run	70,000,000	23,475,000	93,475,000
long-run	120,000,000	23,475,000	143,750,000
secular (I)	-	3,266,000,000	-
secular (II)	-	15,050,000,000	-

Naturally, the two secular versions are entirely meaningless in light of annual nickel extraction figures of about 1,000,000 metric tons. However, they are all the more meaningful in discarding the Dennis Meadow fallacy of the limits to growth due to resource exhaustion.[46]

Finally, the comparison between land-based laterites and sulfide ores showed that, as to nickel content, the laterites can compete against each other. However, these minerals

differ with respect to the content of other metallic minerals. The sulfides hold gold, silver, the PGMs, cobalt and copper. The land-based nickel laterites are poor by comparison. They usually contain iron and chrome.

The sea nodules, which are laterites, especially those of the Pacific type, are composed of a much greater variety of metallic and other minerals than their land-based laterite competitors. They contain manganese, cobalt, nickel and copper to name the most important ones. Through this variety, they compete against the land-based sulfides, especially through the copper component. Nonetheless, they cannot hold out against the precious and noble metal content of the sulfides which remains, perhaps, the final trump card of the sulfide ores!

Alternative Suppliers

The purpose of the following discussion is to bring to the fore as much as is possible, the almost unbelievable nickel investment activites which presently are taking place in other countries. This means that only the land-based operations are being discussed. To this area of feverish activities, the preparations by the private sea-bed mining consortia will have to be added and the discussions at the United Nations leading possibly to an international sea-mining unit - the Enterprise, However, the scope of these investments have not been analyzed

in this section due to a lack of information. Yet, one thing is certain: these plans are in progress!

U.S.S.R.

Relatively little is known about the nickel activities and expansion plans in the Soviet Union for the years after 1980. However, in the past, this industrializing country has displayed an unusual growth in nickel production. Starting in 1975, the U.S.S.R. reportedly was in the process of raising its nickel production by between 20 and 30 percent by the year 1980. Nickel production for 1975 had been 152,000 metric tons. In 1979, output had not changed at all, as indicated by the respective estimates of the United Nations,[47] which reflects the general conditions of information.

Half of the nickel reserves of the U.S.S.R. are low-grade silicate ores, that means laterites. The other half consists of sulfide ores containing copper, cobalt and the PGM metals, especially palladium, gold, silver and selenium. The sulfides are located at two points: the one is the Norilsk - Talnakh district in Krasnoyarsk Kray of Eastern Siberia; the other is in the Pechenga-Monchegorsk area of the Kola Peninsula.

The (laterites) oxides are produced in the Aktyubinsk area of the Southern Ural, in the Ufaley area in the Central Ural and in the Ukraine. By order of significance, Norilsk-Talnakh is in first place, followed by the Ural and then by the Kola Peninsula deposits.

The most important smelter complex is at Norilsk, followed by others at Ufaley, Rezh and Khalilovo as close seconds; the Monchegorsk and Pechanga smelters are third in significance and the ferro-nickel operations at Pobuzhek are in fourth place.

As to further nickel production, expansion will continue at the Norilsk complex where investment plans envisaged a total expenditure of 1 billion roubles for 100,000 tons of refined nickel utilizing in the U.S.S.R.,for the first time, autoclaves in the non-ferrous metallurgical field. Activities at the Oktyabre mine at Norilsk has been continuing with the sinking of new shafts and with further prospecting north of Norilsk. It is reported that 30 exploration teams have been at work involving 270 persons.[48] However, certain shortages seem to have materialized in the Kola Peninsula.[49]

Given these activities, it is not far-fetched to assume that by the year 2000, the U.S.S.R. will have a nickel production capacity of 200,000 metric tons of nickel per annum.

Cuba

Cuba, with its huge laterite deposits has to be included at this point in the discussion. With a grade of 0.8 to 1.4 percent, this country had ambitious plans for the production of nickel. By 1985, it had hoped to produce 100,000 metric tons per year. Due to delays in construction, the plan had to be postponed by five years. At present, the U.S.S.R. and

COMECON countries are financing $600 million expansion of Cuban nickel production. It was intended to raise the output of the Nicaro plant from 18,000 to 22,500 metric tons per year; to expand the Moa Bay plant from 18,000 to 24,000 metric tons per year and to build two new nickel-cobalt plants of 30,000 metric ton capacity each. One had been expected to be in operation by 1983/84, while the other should have been on stream in 1985/86.[50] It is also of interest to note that Belgian, French and Spanish concerns are involved in a $500 million steel plant construction project in Oriente Province partly financed through buy-back provisions. A cellulose and paper factory is being partly financed with a commitment to buy back nickel.

U.S.A.

Nickel production in the United States was 830 metric tons in 1950 and 12,790 metric tons in 1979. It is quite obvious that this country will not be an alternative supplier in the world market. However, to the extent that the nickel output in future years may substitute nickel imports from Canada, there is no doubt that the demand for Canadian nickel may be affected.

As mentioned above, there are two main nickel producers in the United States: one is the Hanna Mining Company with its operations in Riddle, Oregon; the other is the AMAX Company

which refines imported nickel matte into nickel at its refinerv in Port Nickel La. Additional nickel comes as by-products from copper refining and from other, secondary supplies, such as from nickel alloys, stainless and alloy steel scrap and processing residue.

In light of the fact that the United States consumed 182,400 (primary refined) metric tons of the metal and that its mines only extracted 12,790 metric tons, other sources had to fill the need. A definite dependence on other sources exists. It is, firstly, reflected in 47,000 metric tons produced from secondary sources which is almost 4 times the mining output. Specifically, this breakdown explains part of the relationships:

	1979	
Primary Production	12,790 metric tons	5%
Secondary Production	42,638 metric tons	17.3%
Total Consumption	246,486 metric tons	
Primary Refined Consumption	182,075 metric tons	
Net Import Dependence		77.7%

A large dependence on imported nickel prevails for the United States. The main sources of imports are: Canada, with 54%, Norway 9%, New Caledonia 8%, Dominican Republic 6%, and 23 percent coming from other countries. It is, of course, evident that the nickel imported from Norway is partly of Canadian

origin but cannot easily be added to the Canada total. Otherwise, this addition could demonstrate even more the degree to which Canada , for the exports of nickel, depends on the demand of the United States,a point which was brought out in the discussion of the Canadian nickel trade.

Among the other countries which supply nickel to the U.S.A. is the U.S.S.R. It is reported that the U.S.A. imported $12.4 million worth of unwrought nickel in the first nine months of 1978. At $2./lb, this would be equivalent to 6.2 million pounds or to about 2,810 metric tons that came to the United States from Russia.[51]

Two points will have to be considered briefly. At first, there is the possibility of opening up lateritic nickel deposits in California, Washington and Oregon. No definite plans have been announced in the literature consulted so that nothing explicit can be said. However, it is important to know that the new administration in the United States has placed nickel on the priority list of strategic stockpiles.[52] At the end of the year 1979, the announced goal had stood at 185,372 metric tons, but the government bins were absolutely empty.[53] Bearing in mind also the general balance of payment problems, it would be reasonable to see the U.S.A. expand the use of their own nickel ores. This may eventually include the land-based Duluth gabbro

deposits. Yet, in light of their poor grade, it is more likely that sea-bed mining will provide a very quick solution to the problem, especially in light of the change in opinion concerning UNCLOS as indicated by the White House which would not see an early agreement in respect of the International Law of the Sea.

The second point has to do with the other nickel-producing countries in the world. The extremely large share of nickel absorbed by the United States which is largely supplied by Canada must be very attractive to foreign competitors; there is no doubt that the degree to which these countries are expanding their nickel capacities, will be aiming at exports to the United States. It is, therefore, on two fronts that Canadian nickel exports are vulnerable as regards its most important customer. These events from outside and from within the U.S.A. are beyond Canadian control unless the main Canadian producers have been able to join the operations on those fronts. Eventually, it will be the lowest cost producers which will hold the field even if he is subsidized! This is so because there is an international market which is now very much more competitive than it was in the 1930s!

The Philippines Output 1979: 36,000 metric tons

At present, two companies dominate the nickel mining

picture in the Philippines: (1) Marinduque Mining and Industrial Corporation and (2) the Infanta Minerals and Industrial Corporation. The first company is in the process of expanding its ore extraction and concentrator capacity by 177 percent in 1982 over that of 1979/1980. The daily output of ore will rise from 18,000 metric tons per day to 25,000 by 1981 and to 50,000 in 1982. This will take place at the Sipalay plant in Negros. This would mean that output of the Philippines can be expected to double in the foreseeable future. The amount of required investments, unfortunately, has not been stated in the sources consulted.[54] Since these ore are energy-consuming laterites, it is of interest to note that the Philippines are determined to break the import dependence in this regard. Coal and oil drilling projects are on the way to remedy the difficult balance of payment situation. Such efforts will not fail to bear fruit in producing energy necessary for the processing of nickel ores.

Indonesia Output 1979: 35,690

The efforts in this country to raise the output of nickel should not be underestimated. Reportedly, Indonesia lateritic has ore reserves amounting to 824 million tons which would make it into one of the largest land-based nickel reserve holders in the world.[55] In essence, there are five

main operators at work in the nickel field.

The oldest of them is the state-owned mine at Pomalaa which includes a ferro nickel smelter. The output of this complex has always been absorbed by the Sunideco group of Japanese ferro nickel processors. Indications are that the capacity of the Pomalaa plant is around the 5,000 metric ton mark,[56] with no immediate expansion plans recorded.

P.T. International Nickel (INCO) is the next company of importance with an operation at Soroako in South Sulawesi. This company has experienced difficulties with refractory erosions due to high acidity levels of slags. By November 1979, the No. III Furnace was commissioned on schedule such that the plant will be able to bring production up to some-what modified capacity of 75-80 million pounds (34,000-36,250 metric tons) of nickel. Output is expected to be around 60-65 million pounds (27,200-29,500 metric tons) by 1981.[57]

The third company of interest is P.T. Aneka Tambang. It has started to exploit the Oeboelie deposit on the equator-ial Gebe Island situated between the Islands of Halmahera and Iranian Jaya. Intentions are to raise exports from the 1979 level of about 450,000 tons to 800,000 and later, after proper harbour facilities have been built, to between 1.4 and 1.5 million tons. Assuming a grade of 1.5 percent, this would be equivalent to a nickel content of between 12,000 and 22,500 metric tons per year. The economic advantage of

this mining site is that it is a very short haul from shovel to dump-truck and then to the barge which takes the compass course straight north to Japan.

In addition, the Indonesian Nickel Development Corporation (Indeco) has entered a partnership with a number of Japanese smelting steel and trading firms to investigate the construction of a smelter on Gebe Island. This smelter would have a capacity ranging between 23,000 and 45,000 metric tons of ferro nickel ready for shipment to Japan.[58]

Finally, there is the huge project of P.T. Pacific Nickel on Gag Island. It involves a consortium consisting of U.S. Steel, Hoogovens, Amoco and Esfel, with the U.S. Steel as the operator. The plan is for the construction of an open-pit mine and a smelter to produce 50,000 tons of nickel per year. The investment cost has been revised to the amount of $1,450 million with completion expected by 1983/84.[59]

In short, by the late 1980s, it would appear that the capacity to produce nickel would be between 125,000 and 150,000 metric tons compared to an assumed capacity for 1979 of 50,000 metric tons.

New Caledonia

Two major projects are under way in New Caledonia: one runs under the name of Cofremmi through which BRGM holds

mineral claims over very large deposits at Poum, Teibaghi and Ile d'Art in Northern Caledonia. This company has been taken over by a newly formed holding company with the name of Société de Promotion des Mines owned to 49 percent by AMAX and to 51 percent by BRGM[60] and it will spend $600 million on a mine and plant operation to produce between 25,000 and 30,000 tons of nickel per year. The mineral resources amount to 50,000,000 million tons of ore, containing 2.5 percent nickel or 1,250,000 of nickel. This production facility will be located at Koumac and it is expected to be on stream in 1983.

The second project involves the company Le Nickel (SLN) with an investment of $200 million. The plans are to increase the output at the Donaimboo smelter (from 85,000 pounds of nickel to 100,000 pounds). This amount includes expenditures on the doubling of the mine output at Kouaoua from 600,000 to 1,200,000 tons per year plus a 200,000 tons per year ore facility at Nepoui.

In short, $800 million are earmarked for investment in nickel in New Caledonia.

Australia

Australia, which exports 90 percent of its nickel to Japan, Europe and the United States and Canada, experienced a new demand for nickel from the People's Republic of China in the year 1979. Besides the discovery of a new nickel

deposit in the Mount Keith area of Eastern Australia, the Western Mining Company is in the process of constructing a 100,000 tons per year nickel concentrator and smelter in Kalgoorie in Western Australia. This plant is to process the Agnew Mine output. The cost of this investment is in the neighbourhood of $100 million.[61] The Seltrust Holdings Company-Selection Trust Limited and MIM Holdings Limited - plans to raise the output from the present 10,000 metric tons to 15,000 per annum over the next ten years.

Furthermore, Metals Exploration and the Finnish firm of Outokumpu Oy are undertaking a feasibility study whether or not to open a new nickel ore deposit Widgiemoolta. No further information is available from the sources consulted.

New Zealand

Although information is sparse, it was announced in 1979 that New Zealand Nickel Smelting Company had planned to invest $120 million to build a nickel smelter at Greymouth. This smelter would be close to the seashore and to the mining site. The more recent literature does not confirm this project!

Colombia

In the year 1956, a huge deposit of laterites nickel ores was discovered amounting to 25.5 million tons with the top grade of 2.67 percent nickel. A company has been formed, led by the government-owned Econiquel with 45 percent share

ownership, Billiton (Royal Dutch Shell subsidiary) with 35 percent and Hanna Mining, holding 20 percent of the ownership. The intention is to exploit the Cerrama deposit which is located 250 miles northwest of Bogata in the Department of Cordoba at an initial estimated cost of $315 million. An open-pit mine and a concentrator are planned to produce 60,000 metric tons of ferro nickel containing 37.5 percent nickel and 62.5 percent of nickel iron. Billiton has contracted to absorb the output containing a possible 22,500 metric tons over the first 12 years of operations. Financing has been secured through the World Bank, Chase-Manhattan and the U.S. Export-Import Bank. Alternative sources of energy in the form of natural gas or coal are easily available for smelting of the ores. The plant should be on stream in 1982.[62]

Brazil Production 1979: 4,000 metric tons[63]

Brazil has not been self-sufficient in its consumption of nickel.[64] However, large investments are undertaken to change this situation. The Morro do Niquel Company supplied 2,210 metric tons in 1979 which was about 3,500 metric tons in 1978. The first of the projects of expanding nickel output of Brazil was the formation of the Companhia Niquel Toncantins in the Niquelandia District. This is an open-pit mine, including a smelter with a capacity of producing 5,000 metric tons annually which may be increased to 10,000. This

plant started to operate in the middle of the year 1979, and thus contributed to raising the output for that year to to above-mentioned figure.

The second project was the $98 million investment by Empresa de Desenvolvimento de Recursos Minerais SA, generally called Codemin, to establish a ferro nickel smelter which was to be in operation by 1981/1982. Financed by the International Finance Corporation, this project of the Brasimet Group in which apparently the Anglo-American Corporation has a minority interest will have a capacity to produce 5,000 tons of nickel.

Following the report of the Engineering and Mining Journal[65] another two projects are in the planning stage. They involve the Baminco Mineracao (INCO) Companhia, which plans to build an open-pit mine and a smelter in Barro Alto in the state of Goias. The investemnt would be $260 million to produce 50 million pounds of ferro nickel. The nickel content would be between 8,500 and 10,000 metric tons.

If one follows the same source, then the Companhia Vale do Rio Doce is in the process of planning the construction of an open-pit mine and a refinery in Sao Joao do Piaui. The aim is to produce about 9,000 metric tons of nickel annually from an orebody of 20 million tons with a grade of 1.7 percent nickel. $100 million are ear-marked for this expansion.

If all plans materialize, Brazil's nickel capacity will exceed 35,000 metric tons in the foreseeable future. This is equivalent to a tenfold increase of Brazil's output of this important metal, and more than $458 million will have been allocated for these purposes in Brazil alone.

South Africa

A small addition to the nickel refining capacity of South Africa is under way. Matthey Rustenberg Refiners are in the process of replacing the former refinery with a capacity of 15,000 tons per year by a new one able to handle 18,600 tons per year. This would correspond to a 10 percent increase in the output capacity of this country. Nickel is a by-product of the platinum metal operations coming from the Merensky Reef.

Greece Output 1979: 20,600 metric tons

Greece mills about 3 million tons of laterite ore per year. It has been recognized in Greece that the demand for nickel is subject to changes. Two factors have been noticed. For one, stainless steel production outside Greece has led to rising consumption demand for that metal; for another, it is also reported that the Sudbury strike of 1978/79 created a heavier demand for nickel from other producers.[66] The

International Minerals/Metals Review, 1980 continues with this observation:

> «These developments have created a psychological climate prompting stainless steel producers to stockpile nickel to guard against future INCO labour strikes...»[67]

In addition, the Greek government has plans to build a 50,000 tons/year stainless steel industry which would absorb additional nickel. So far, Larco S.A. invested about $75 million and raised production in its Larymna facilities from 15,000 to 27,000 tons. Larco is also reported to have long-run plans to increase its capacity finally to 40,000 tons of nickel. This would involve another $170 million.[68]

In addition, the Scalistri Company plans to place $65 million into a mining plant to produce 40,000 tons of ferro nickel per annum; the assumed nickel content would be at least 10,000 tons. A conservative estimate could see Greece's long-run potential to be 50,000 tons of nickel.

Yugoslavia Output 1979: 1,500 metric tons[69]

This country, too, is on the way of becoming an important nickel producer. Following M.J. Gauvin, Projmetal has been building two smelters - Goles and Rzanovo - at Kasovo Mitrovica at a cost of $97 million. These two smelters have reportedly a capacity to produce 28,500 tons of nickel, and they should have been operating in 1980.[70] Furthermore, Feni-Ruduici is sinking $ U.S. 187 million into a nickel mining and smelting

operation to produce ferro nickel with a nickel content of 19,000 metric tons.[71] This plant is to start in 1984. These projects would bring the nickel output capacity of Yugoslavia close to 49,000 metric tons. Considering that Yugoslavia's domestic demand gap in 1979 was about 2,000 tons of nickel,[72] the effect of these excess quantities on the world market would be quite obvious should that gap stay the same or become smaller!

In short, the alternative suppliers of nickel outside Canada have earmarked over $4.4 billion for the expansion of nickel production in the resource holding countries. In terms of additions to output, the approximate total is 363,000 metric tons. If one considers that in 1976, 804,000 metric tons of nickel were mined world-wide, the increase in potential output by the middle of the 1980s would be 45 percent. This increase does not include planned output expansion of nickel production of the Soviet Union for which no conclusive evidence has been available. Yet, most of all, it has to be born in mind that these projects are forged on the land-based mineral deposits of nickel oxides, the laterites!

To round out the discussion, in the course of this investigation, it has become clear that certain companies in the field of nickel refining are producing above original capacity estimates. Due to technological change and, possibly, other efficiency measures, two Japanese firms have set

examples in this direction.

There is the Sumitomo Metal Mining Company which has developed a process to separate nickel and cobalt by solvent means. As a result, nickel production increased from 1,670 to 1,920 metric tons per month. Reportedly, the company was awarded the so-called Watanabe Prize for this increase in capacity by 15 percent.[74] In a similar efficiency effort, the Saganoseki smelter of Nippon Mining succeeded in exceeding its nominal capacity of 1,150 metric tons per month by 308 metric tons or by 26.8 percent. This is reported for two out of the eleven mostly lateritic nickel processing companies of the industrial country of Japan.

SECTION V: THE FUTURE OF NICKEL: PRICES, SUPPLY AND CONSUMPTION

Prices

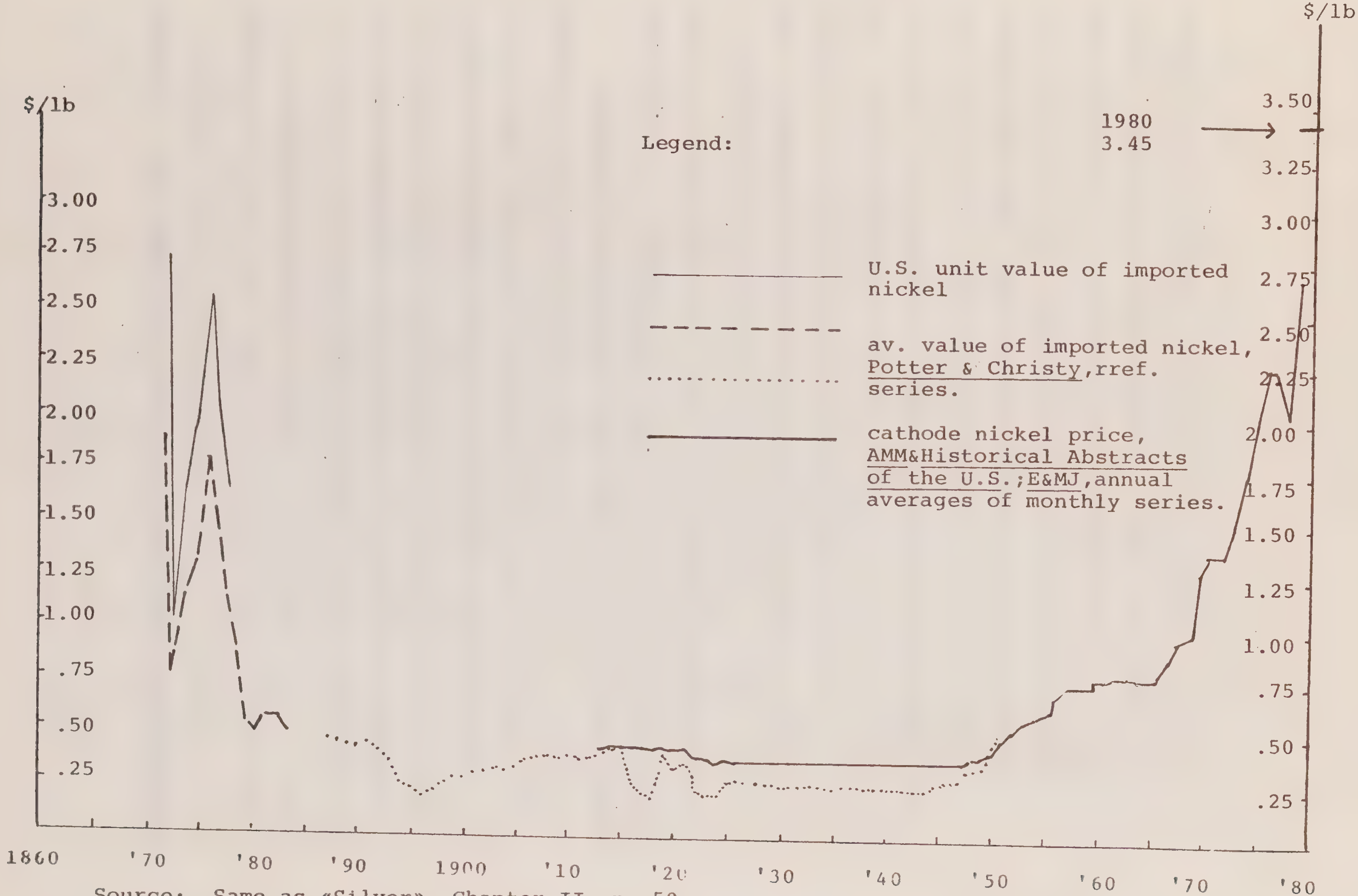
Historical Prices

It is certainly surprising to find that nickel prices in the United States were as high as $3.25/lb in 1849. Following Schmitz,[75] the price of this metal stood at $1.12/lb in 1830. It fell to $1.00 ten years later, climbed to the mentioned peak in 1849. Over the next decade, it stayed in a range between $1.12/lb and $1.57/lb (1871).

Exhibit 1 displays the general behaviour of nickel prices thereafter.[76] It appears that nickel was almost a semi-precious metal in those early days. Until 1876, prices remained high in comparison to what was to lie in the future. After this year, a substantial decline set in as New Caledonia made its presence known as the world's largest nickel producer.[77] By 1896, nickel had arrived at the lowest price ever. It sold for ¢18/lb. In 1906/7, it reached ¢38/lb and maintained that level until 1913. From then onward, producer prices were listed separately. They remained stable at ¢35/lb from 1926 until 1946. Only the average value of imports - the dotted line in Exhibit 1 - are below the producers price. From 1951 onward, the price of nickel started to rise; at first, the movement was slow which lasted until 1966, when it sold for

Exhibit 1

Nickel Prices in Current $ U.S. for the Years 1871 to 1980



Source: Same as «Silver», Chapter II, p. 59.

¢79/lb. Afterwards, the speed of the rise accelerated ending at $2.72/lb in 1979 and averaging $3.45/lb in 1980. In this fashion, a U-shaped price behaviour curve can be distinguished starting out with about the same price of around $3.25 ($3.45/lb) in 1849 which, in nominal dollars, is reached again some 130 years later, after hitting a low of ¢18/lb at the end of the 19th Century.

The Future Prices of Nickel

Following Exhibit 2 and Table 10, the price of nickel, when measured in constant 1979 $ U.S.,will be relatively stable in the first four years, rising from $2.92/lb in 1980 to about $3.43/lb in 1984. By 1988, it will approach the $4.00 mark and in 1994, it is predicted to sell for $5.13, provided one is willing to see so far into the future. If one is courageous enough, a price of $7.00/lb of nickel may be acceptable by the year 2001, and three years later, it would approach the $8.00 mark.

This forecast definitely tells one thing: viz. that the real cost (and price) of producing a pound of nickel will be twice when the century draws to a close than what it was at the beginning of the forecast period in 1980. For all intents and purposes, this is not an unreasonable assumption!

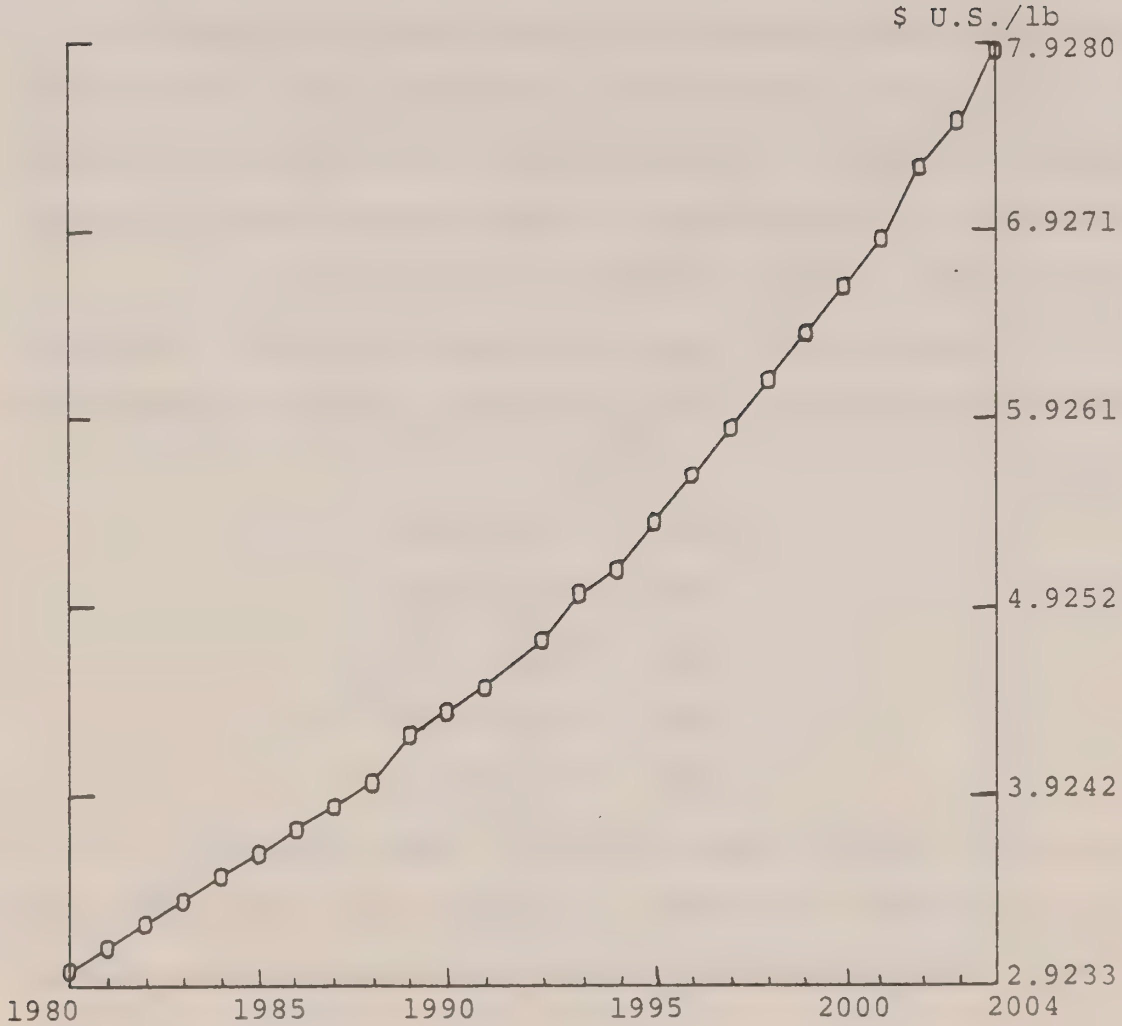
TABLE 10

Nickel Prices (in constant 1979 $U.S./lb
Production and Consumption (1000 metric tons)
for the years 1980 to 2004

YEAR	PRICE	PRODUCTION	CONSUMPTION
1980	2.9233	733.04	666.62
1981	3.0676	781.15	692.88
1982	3.1883	822.63	716.07
1983	3.3050	859.45	737.14
1984	3.4265	893.31	756.83
1985	3.5561	925.45	775.70
1986	3.6948	956.75	794.08
1987	3.8427	987.77	812.23
1988	3.9996	1018.87	830.27
1989	4.1655	1050.28	848.29
1990	4.3404	1082.13	866.35
1991	4.5244	1114.50	884.48
1992	4.7177	1147.46	902.70
1993	4.9206	1181.05	921.02
1994	5.1336	1215.28	939.45
1995	5.3571	1250.19	957.99
1996	5.5914	1285.79	976.65
1997	5.8373	1322.10	995.44
1998	6.0953	1359.14	1014.36
1999	6.3658	1396.93	1033.41
2000	6.6496	1435.48	1052.59
2001	6.9471	1474.81	1071.92
2002	7.2589	1514.93	1091.38
2003	7.5856	1555.85	1110.99
2004	7.9280	1597.60	1130.74

Exhibit 2

Nickel Prices in constant 1979 $ U.S./lb for the Years 1980 - 2004



Future Nickel Production

As shown in Table 10 and Exhibit 3, annual demand for mine production of nickel was predicted to be 733,040 metric tons by 1980, this means last year. In the following years, predicted nickel supply will rise to 925,450 metric tons for the year 1985. Five years later, the econometric model foresees a world nickel mining output of 1,082,130 metric tons. By 1995, annual production of this metal will stand at 1,250,190 metric tons, while 1,435,480 metric tons are projected as the world mining output in the year 2000. At the end of the forecast period, annual mining output of nickel should have reached 1,597,000 metric tons.

Cumulatively, during the first six years, 5,015,000 metric tons will have been exploited. As the breakdown indicates -

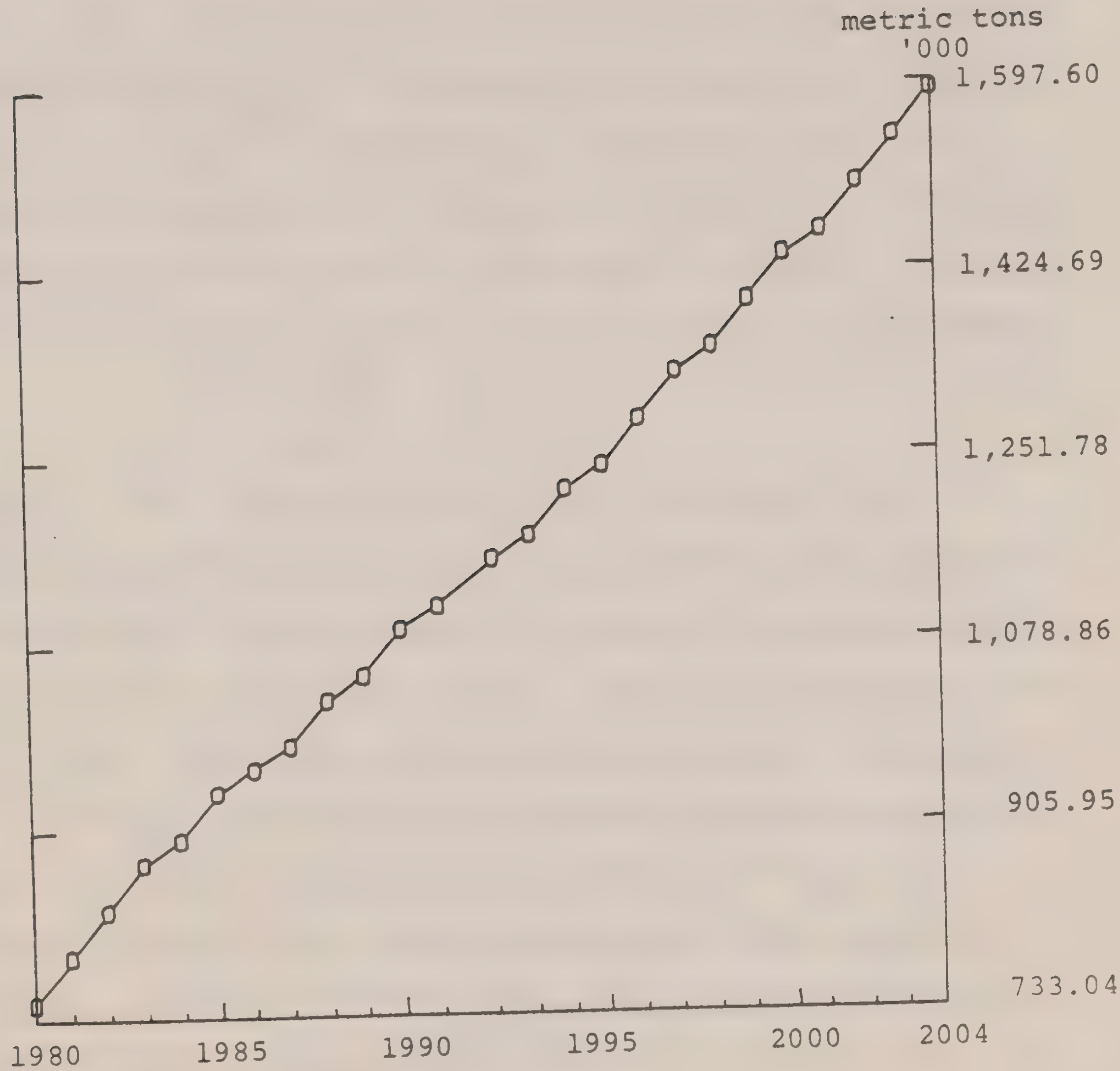
1985	5,015,000
1990	10,110,820
1995	16,019,310
2000	22,818,750
2004	28,961,940

about 10.1 million metric tons will have been taken out by 1990, a figure which will reach 16 million metric tons five years later. At the beginning of the next century, more rapidly

Exhibit 3

World Nickel Mining Supply for the Years 1980 to 2004

in '000 metric tons



rising production demand will have contributed to a cumulative extraction of 22.8 million metric tons of nickel, while at the end of the forecast period, total mined nickel from 1980 to 2004 will amount to almost 29 million metric tons.

In comparison to the production-demand forecasts of other authorities in the field, the following picture unfolds: (in '000 metric tons)

Year	E. Willauer	Malenbaum[78]	U.S.B.M.[79] (primary)	UNCLOS[80]
1985	925	905	916	989.3
2000	1,435	1,314	1,442	1,914.6
2004	1,597	-	-	2,283.2
2000			max. 1,724	
2000			min. 1,170	

This comparison brings out very clearly the closeness of the first three predictions. For the year 1985, the econometric forecast (Willauer) is slightly above both Malenbaum's and that of the U.S.B.M. For the year 2000, this prediction (Willauer) lies right between the two, that means above Malenbaum's and below that offered by the U.S.B.M. in 1974.[81]

It is also of critical importance to realize the unusually high figures of future nickel demand projected by the United Nations Conference of the Law of the Sea (UNCLOS). It exceeds any of the three other predictions by very large margins. That particular forecast started in 1977 and, apparently, had

been based on the consumption of the years 1970-1976 with 665,700 metric tons as the actual starting value for 1976. The assumed growth rate of nickel demand was 4.5 percent as stated in the Informal Sub-group of Technical Expert's Chairman's Report, 16, February, 1978. Suffice it to comment that basing such a long projection on the annual data of merely six years would, from the academic point of view, cause serious raising of eyebrows; and to use these forecasts as one of the underlying premises of so important a conference means placing the arguments surrounding the future of sea-bed and land-based nickel mining on foundations of questionable validity. It can only be hoped that this forecast has been revised in the meantime!

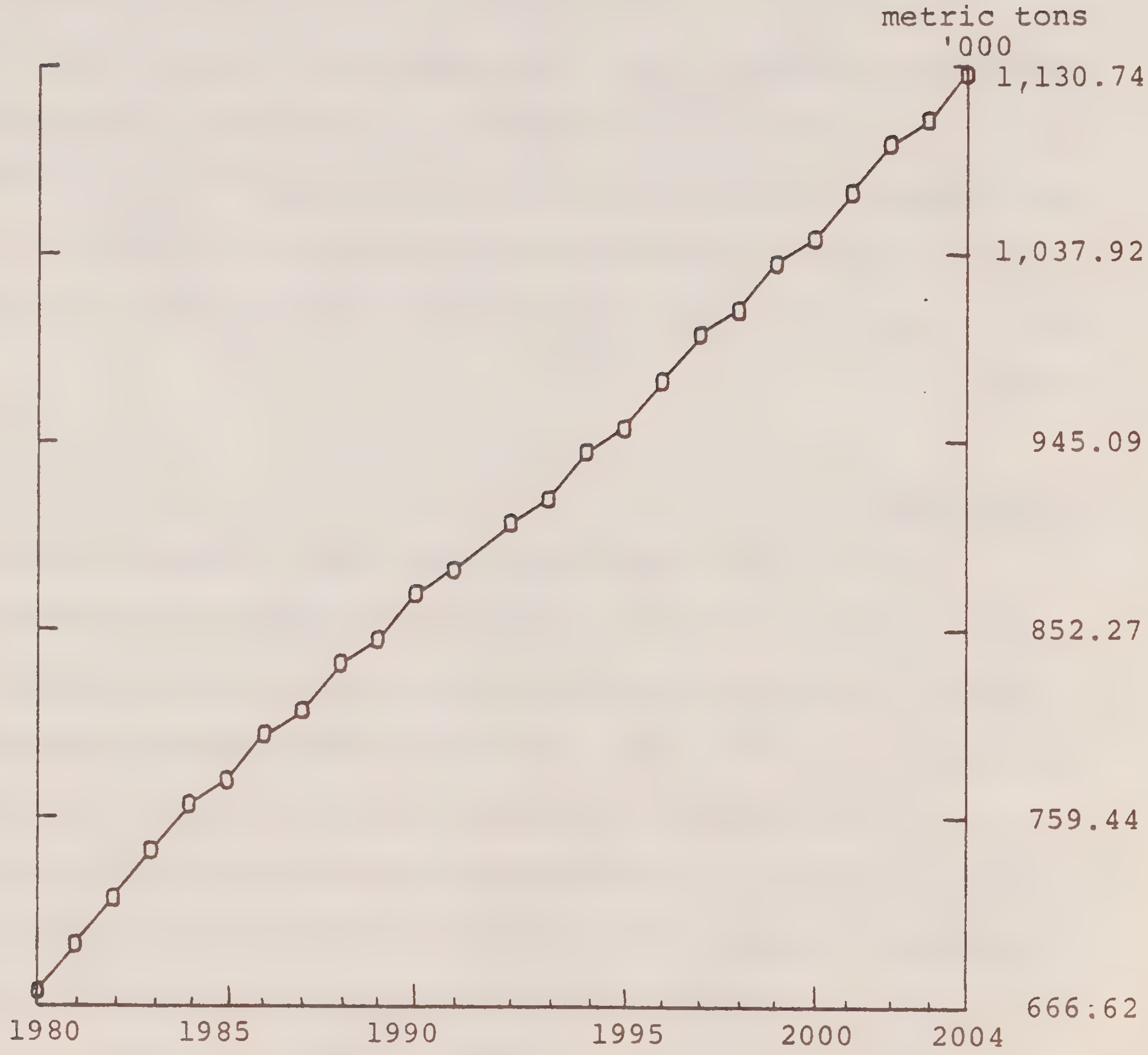
Consumption

The future of consumption of nickel is shown in Table 10 and in Exhibit 4. These projected consumption values are consistently below the production values with the gap widening in the far future. The main reason for this apparent discrepancy is that the econometric analysis placed considerable emphasis on price, supply and the demand of mined nickel. The actual consumption variable is of minor interpretive significance as its main purpose was that of a mathematical-technical variable for closing the multiple equation system!

Exhibit 4

World Consumption of Nickel for the Years 1980 to 2004

in '000 metric tons



SUMMARY AND CONCLUSION

Nickel is a hard metal resisting corrosion and bestows these and other of its qualities on to metals with which it is alloyed. It is used also in batteries, as catalysts and - as money!

Nickel mineralizations and ores occur in laterites, sulfides and lateritic manganese sea-bed nodules. There are a number of possible substitutes of somewhat questionable efficiency. Most of them are more expensive than nickel, which is relatively cheap. Therefore, nickel has a substantial competitive edge over those other substances.

In modern industrial society, nickel is used mainly in stainless and other steels, in numerous alloys, in electroplating and in high temperature and electrical resistance alloys. Its use in cast irons and in 'other uses' is on the decline.

With the U.S.A., Japan and the Soviet block countries as the largest industrial consumers of nickel, there is no doubt that consumption of nickel will continue to rise as increasing world-wide industrialization cannot fail to absorb ever and ever larger quantities of this reasonably priced metal for decades to come. This holds true, especially in light of the possible industrialization of the developing countries in the continental regions of Africa, America, Asia and Europe.

World mine production has risen at a similar rate over the period under study as has consumption. Historically, Canada - and Ontario - became the most important of six nickel producers in the world in the 1930s. However, substantial ground was lost as new nickel ore producers entered the global scene. By 1977, with over 22 countries supplying nickel, Canada produced less than one third of the nickel in the world. Still, it remained the largest producer in the world followed closely by New Caledonia and the Soviet Union.

Canada is a significant net exporter of nickel products and mainly ships this metal in refined forms and as ores and concentrates. In addition, Canada smelts and refines ores from other countries and, if all is totalled up, not less than 70 percent - sometimes around 100 percent - of annual production find their way into international trade channels.

World smelting and refining capacities have substantially increased between 1956/57 and 1979. The five largest processors of nickel are Canada, Japan, the U.S.S.R., Australia and New Caledonia. They are followed by medium-sized nickel processing countries. In alphabetical order, they are: Botswana, Cuba, the Dominican Republic, Indonesia, Norway, the Philippines and South Africa. Finally, there are the other countries classified as small processors. Yet, there is no country to match Japan's meteoric rise as a nickel processor.

Essentially, there are two types of nickel-bearing

mineral deposits: land-based and sea-bed minerals. The conventional resources under present exploitation are the former while the latter do display definite competitive qualities such that they will enter the market sometime in the future.

In the long run, it would appear that New Caledonia is the largest land-based resource holder, followed by Cuba, and then, Canada. The United States is fourth, due to its low-grade Minnesota gabbro deposits. The U.S.S.R. is in fifth place, followed by Australia and the Philippines. Finally, Indonesia is seventh in the world. It stands to reason that all these reserve figures are tentative and are very open to criticism.

The sea-bed nodules do change the reserve picture substantially. The short-run reserves are increased by 33.5 percent, while the long-run total increases by 19.8 percent due to the inclusion of these short-run nodule potential. Although at present, the actual competition is fierce among the sulfides and the land-based laterites, there is no question that the nodules will soon enter the competitive game, at least as the short-run reserves are concerned.

The nickel oxides - land-based or sea-bed nodules - are intensive energy users compared to the sulfides. In turn, the recovery cost of the land-based laterites is least among all resources. However, the composition of the land-based laterites is limited to a few metals, whereas the sea-bed nodules,

especially in the Pacific Ocean, contain many other interesting mineral elements, especially manganese, cobalt, copper besides nickel. Yet, the variety of mineral components of sulfides excels through gold, silver and the PGMs.

Alternative suppliers outside Canada have earmarked, if not committed, over $4.4 billion - not counting the 1 billion roubles which the U.S.S.R. has invested since 1975 - to develop mostly lateritic deposits. The expansion from these possible sources would at least add 363,000 metric tons if all planned projects are carried out. This would most likely occur by the middle of the 1980s. Add to this the successes in improving efficiency scored by the lateritic nickel processors in Japan, then, it should be clear that the nickel market will experience unusual competitive pressure from alternative suppliers, especially from the lateritic ones. That pressure, ceteris paribus, will be strong, not to say overwhelming.

Historically, the price of nickel took the course of a U-shaped curve, showing a very high value at $3.25 as early as 1849; but it was very low before the turn of the century as it sold for ¢18/lb. It remained very stable around ¢35/lb for a long time in the 20th century, but eventually, it started to rise and by 1980, it reached $3.45/lb (current dollars U.S.).

The price of nickel, in constant 1979 $ U.S., will rise slowly, and by the end of this century, it will have doubled. This means simply that it will cost twice as much in real terms to produce one pound of this important metal by the year 2000 than it did in 1980.

World production of nickel is forecast to rise from 733,000 metric tons annually in 1980 to 1.4 million metric tons by 2000. Four years later, in 2004, almost 1.6 million metric tons will have to be mined according to the econometric prediction. This amount is much below the one initially established for the UNCLOS. Cumulatively, 28.96 million metric tons will have been taken out of the ground - and to some degree - from the sea.

The following conclusion may now be drawn:

(1) In light of the abundance of nickel resources, there will always be plenty supply to satisfy future consumption demand, and the cumulative exploitation over the next twenty-five years will not affect the short-run reserves to any serious degree, especially since rising prices will enlarge the available resources for the short run;

(2) However, until 1995, ceteris paribus, the world will continue to be plagued by excess capacities as producing countries may be geared up already by 1985 to produce quantities demanded only ten years later. The distribution of excess capacities

will be unevenly felt in the producing countries as the laterites will make increasing inroads into the field occupied by the sulfide-based producers with effective competition stemming chiefly from more efficient smelting and refining operations in Japan while disturbances may also be caused through activities such as the buy-back operations due to Cuban investments.

It follows that the Canadian operations will continue at existing levels which depends on the U.S. demand for this metal rather than anybody else's. However, Canada's world share of production will continue to decline due to the present competition of the laterites and the later one from sea-bed nodules which, in turn, must also affect the other lateritic land-based operations. This excess capacity will overhang the market unless the U.S.A. - and other countries - will modify the course of events. On the part of the United States, essentially three measures may act as modifiers:

a) the U.S.A. replenish quickly the strategic stockpile of nickel; however, this policy will only be of short duration and limited benefit to the industry;

b) the United States - and here may be included the possible activities of other countries of the Western World - start to rearm in earnest and carry this effort far over the next fifteen years; and

c) technological change will bring the electric vehicles on a

large scale into this world. In this case, nickel-battery driven cars will be able to absorb the excess capacities easily, even if rearmament should fail to generate the required absorption. Some estimates have been ascertained as to possible future demand for nickel which these new vehicles would impose on the various metal industries.[82] However, caution is suggested in taking these estimates too literally, because other substitutes in automotion will likewise see the light of day.

As regards the United States, these possible modifications are incompatible with the current balance of payments position of the United States, a situation which can be expected to be remedied in a number of years hence. Since any expansion of nickel mining by the United States will take a number of years to materialize, the initial requirements for replenishing the empty stockpile and part of the military beefing-up will have to be satisfied with imported nickel from Canada and from the Canadian competitors, whoever they are. Therefore, the increased demand from which the Canadian operations may benefit will be of a temporary nature only, because the United States may open up both the laterite deposits in the West and the low-grade Duluth gabbro deposits in the centre. Eventually, they may start sea-bed mining much earlier than expected. These three potential areas of additional

nickel supplies for the United States may finally require subsidization just as it is extended in other countries, especially in the centrally-planned economies. Under these conditions, world nickel production would be further distorted as new capacities will be created without the proper utilization of customary and existing resource capacities.

(3) Under ceteribus paribus assumptions - meaning under normal conditions without remedial measures coming into effect as suggested under the stockpiling and rearmament programmes - sea-bed mining could not feasibly be phased in before 1995, when the additionally created capacities of the land-based producers should be under satisfactory utilization. If undertaken much earlier, fierce competition might ensue among producing countries with serious disruptive repercussions. This is particularly true since the future world nickel consumption predicted by UNCLOS is unduly optimistic. The introduction of sea-bed mining would only be feasible if no further expansion in the land-based nickel operations takes place after the present plans have been put into effect. The longer an agreement at the UNCLOS is delayed, the smaller will be the productive shares which the land-based mining operators will be able to count on. This is especially true for this country and it is therefore obvious that an early conclusion of these negotiations are in the Canadian interest. Whether such a completion is in the interest of the United States is not up for discussion.

A further word of caution is in order. It should be pointed out that with the commencement of sea-bed mining, huge quantities of manganese and other metals will start to appear in the metal markets which may easily be disturbed by these events. In turn, the prices of manganese and of the other metals may change and affect the demand of substitutes; thereby very low prices of manganese may reduce the quantities demanded of nickel which are, to some degree, substitutes!

NOTES

1 Its scientific symbol is Ni; its atomic weight is 58.70 and it has a specific gravity of 8.8 and a melting point of 1452°C.

2 Jean-Paul Drolet, "Deep Seabed Mining, A Canadian Perspective in Relation to the Nickel Industry," Canadian Institute of Mining and Metallurgy, Address, Sudbury, CIM Chapter, October 19, 1978, p. 27.

3 This event is known as the "Sudbury irruptive." Appreciation goes to Dr. R.A. Cameron, Department of Geology, Laurentian University for this particular point as well as for the encouragement extended in several discussions during this study.

4 John D. Corrick, "Nickel," Mineral Facts and Problems, 1975, U.S.B.M., Washington, D.C., pp. 736-737; especially "uses"!

5 Ibid., pp. 742-743.

6 This increase in the use of oxides may reflect a new nickel product - nickel sinter - which had come into use as oxygen-rich and which facilitated smelting processes.

7 Refined nickel, ferro nickel, nickel oxide and sinter oxide, excluding scrap and nickel chemicals.

8 The statistics have been taken from American Metal Market, Metal Statistics, 1979. A Fairchild Publication, New York, N.Y., p. 151; and previous issues. The value for 1978 was incomplete and had to be adjusted. The 1979 figure was estimated. The more up-to-date values became available only 5 months after the completion of the computer run. Nickel consumption for the world: 1978 = 701,300 metric tons; 1979 = 782,600 metric tons; source. Metallgesellschaft, Metal Statistics 1969-1979, 67th ed. Frankfurt am Main, 1980, p. 57.

9 See Ch. I, p. 28 and p. 53.

10 Ibid., p. 53.

11 Not shown in Table 3.

12 Metal Statistics, ibid.

13 Understandably, these drives towards industrial self-sufficiency will show repercussions on the expansion rate of the customary nickel producers.

14 United Nations Secretariat, "World and Regional Population Prospects," The Population Debate: Dimensions and Perspectives, Papers on the World Population Conference, Department of Economic and Social Affairs, U.N. Population Studies, No. 57 (Bucharest, 1974), pp. 205-206.

15 Except Czechoslovakia.

16 Metal Statistics, ibid.

17 Ibid., p. 52.

18 See "Technical Information Paper," No 2, p. 11 and p. 12.

19 Ibid.

20 Corrick, loc. cit., p. 735.

21 Canadian Nickel Smelters:
INCO Ltd., Sudbury, Ont.
Falconbridge Ltd., Sudbury Ont.
INCO, Thompson, Manitoba

Canadian Refineries:
INCO Ltd., Port Colborne, Ont.
INCO Ltd., Sudbury Ont.
Sherritt Gordon Mines Ltd., Fort Saskatchewan, Alta;
See: M.J. Gauvin, "Nickel, 1979," Preedition Bulletin for Canadian Minerals Yearbook, 1979, Ottawa, p. 8.

22 Due to aggregation of items 255-30 nickel oxide in other and E.E.C. countries, such exports to Japan cannot be verified. In another category, 255-40, nickel and nickel alloy scrap, Japan imported 157 out of 2,382 metric tons of such Canadian exports in 1979 (49/2,308 for 1978, and 73/2,173 for 1977) and, as to item 454-99 - nickel and alloy fabricated materials n.e.s. - 405 out of 11,850 metric tons of Canadian exports in 1979, and 192/14,854 metric tons in 1978. On account of this though incomplete evidence, Japan does not appear to be a significant nickel customer of Canada!

23 Ninety percent of Australian nickel production in 1979 went to the conventional consumers in Europe, the U.S.A. and Japan, with China too showing interest. The Western Mining Corporation Ltd. is the largest nickel producer with a concentrator at Kalgoorlie and a refinery at Kwinana (1974).

24 The Hanna Mining Corporation is the most important nickel (ferro nickel) producer in the U.S.A. with a mine at Riddle in Oregon. It also has a smelter. The AMAX nickel division has a nickel-copper refinery in Port Nickel, La., with an annual capacity to produce 36,280 metric tons of nickel; feed for this refinery comes, e.g. from Botswana and the Agnew Mining area of Australia.

25 In 1979, P.T. INCO Indonesia produced 7,850 metric tons of nickel matte out of a planned capacity of 17,000 metric tons; this matte was exclusively shipped to Japan. See: Ir. Achmad Prijono m.i., "Indonesia," M.A.R. 1980, op. cit., p. 470.

26 Rustenberg Platinum Mines;
Matte Smelters Pty, Ltd.;
Impala Platinum Mines, Ltd.; all three are located at Rustenberg; Botswana, R.S.T. is situated at Pikwe-Selebi of Botswana. See also - Richard Hoppe, "Selebi-Pikwe, - Running a good and tight Underground Mine," Engineering and Mining Journal, February 1980, pp. 55-62.

27 "New Nickel Refinery is Back on Stream at LeHavre-Sandouville," Engineering and Mining Journal, February, 1980, pp. 35-36. In 1979, refinery output was 1,000 metric tons per month. Ibid.

28 W.H. Laughlin, Canadian Reserves as of January 1, 1980, Copper, Nickel, Lead, Zinc, Molybdenum, Silver, Gold, Bulletin of Energy, Mines and Resources, Canada, MR 189, p. 7.

29 Canadian geologists familiar with quality and conditions surrounding the orebody of Sudbury are very quick to respond in no uncertain terms when such ore reserve figures are proclaimed. Their words are so "strong" that their speakers do not like to be identified!!

30 Fleming, loc. cit., p. xviii. This is equivalent to 80 ppm.

31 Corrick, loc. cit., p. 738.

32 Duncan R. Derry, op. cit., pp. 97-98 (Table).

33 Corrick, ibid., Table 2.

34 W.H. Laughlin, ibid.

35 K.P. Wang, loc. cit., M.A.R., 1980, p. 448.

36 Walter Eastman, "Defining the Minimax Orebody," Engineering and Mining Journal, ibid., pp. 72-78.

37 Ibid.

38 Courtesy Department of Public Relations, INCO, June 16, 1981.

39 Corrick, loc. cit., p. 737.

40 Derry, ibid., p. 97.

41 Corrick, ibid.

42 The growth rate is equivalent to a few millimetres per one thousand years, or to one atomic layer per day. Drolet, ibid., p. 28 and 29.

43 Fleming, loc. cit., p. xix.

44 The writer took the liberty to elaborate on these points in reference to maps and on account of his naval experience during and after the Second World War!

45 J.P. Drolet, ibid., p. 33.

46 The untenable position of Limits to Growth is now widely recognized; see e.g. Julian L. Simon, "The Scarcity of Raw Materials," The Atlantic Monthly, June 1981, pp. 33-41, esp. p. 36.

47 Metallgesellschaft, ibid., p. 55 sets nickel mine production at 125,000 and 150,000 in 1975 and 1979 respectively. The UN statistics are based on reports of the U.S.B.M.

48 Strishkov, loc. cit., M.A.R., 1980, p. 600.

49 Ibid., p. 585.

50 Strishkov, ibid.; cf. J.R. Martin, "Cuba," M.A.R. 1980, pp. 413-414.

51 Strishkov, loc. cit., IMMR, 1980, p. 205. Note this quantity appeared at a critical time for the Canadian nickel industry!

52 Engineering and Mining Journal, April, 1981, p. 11.

53 A.B.M.S., Non-ferrous Metal Data, 1979, p. 146.

54 IMMR, 1980, op. cit., p. 523; Engineering and Mining Journal, January 1981, p. 71; also A.F. Disini, "The Philippines," M.A.R., 1980, op. cit., pp. 484-486.

55 At a grade of 1.5 percent, this ore reserve would amount to 12.36 million metric tons requiring an additional upward adjustment over the 7.1 million metric tons of the Duncan R. Derry projection (Table 8, column (1)).

56 See, Ir. Achmad Prijono, m.i. M.A.R., 1980, p. 470.

57 Philip C. Jessup, Jr. "INCO", Bulletin to Shareholders, April 16, 1980, p. 6.

58 IMMR, 1980, op. cit., p. 523.

59 This is the only one undertaking for which a price tag has been easily available; Engineering and Mining Journal, January 1981, p. 71; for revised figures see: Prijonon, ibid.

60 M.A.R., 1980, op. cit., p. 434.

61 Seltrust Holdings at Agnew. $100 million is a later figure given by M.J. Gauvin, loc. cit., 1979, p. 7.

62 E. Schiller, "Colombia," M.A.R., 1980, op. cit., pp. 403-405; Engineering and Mining Journal, January, 1981, p. 71; cf. also M.J. Gauvin, loc. cit.

63 Francisco Alves, "Brazil," M.A.R., 1980, p. 401 places the output at 5,200 metric tons versus an estimated demand of 10,620 metric tons.

64 "Brazil," IMMR, 1980, p. 217.

65 Engineering and Mining Journal, ibid.

66 IMMR, 1980, pp. 132-133.

67 Ibid.

68 Ibid.

69 Metallgesellschaft, op. cit., p. 55.

70 M.J. Gauvin, "Nickel," Canadian Minerals Yearbook, 1978, Ottawa, p. 322.

71 Engineering and Mining Journal, ibid.

72 Karl Lavrencic, "Yugoslavia," M.A.R., 1980, op. cit., p. 614.

73 Excludes Philippines for which no investment cost was available.

74 Saturo Suda, "Japan," M.A.R., 1980, op. cit., p. 485.

75 Christopher J. Schmitz, op. cit., p. 286.

76 Note: Change in source of information: Historical Statistics of the United States, loc. cit. and Neal Potter and Francis T. Christy, Jr., Trends in Natural Resource Commodities, Resources for the Future, 1962, p. 340, MP-17.

77 Corrick, loc. cit., p. 735.

78 Ref. Malenbaum, Engineering and Mining Journal, January 1978, p. 63.

79 Corrick, loc. cit., p. 745, Table 6.

80 See Attachment to J.P. Drolet, "Mineral and other Political Issues," CIM address, Toronto, September 13, 1978, pp. 36-37; also --------, "Seabed Mining," loc. cit., p. 50, in diagramatic form. Courtesy Jean-Paul Drolet, Addresses Presented to the Members of the Canadian Institute of Mining and Metallurgy, President, 1978-1979.

81 The argument of decreasing intensity use of metals is implicitly-endogenously-taken into account by the econometric model. Specifically, the amount of nickel mined (=demand) divided by the GDP index (=units) (without services) is:

$$\frac{PN}{GDP_I} = \begin{array}{l} 1960 : 3.7 \\ 1970 : 2.8 \\ 1980 : 2.3 \\ 1990 : 2.1 \\ 2000 : 1.9 \end{array}$$

82 *Metals Week*, April 7, 1980, p. 6,"Metal supplies will tighten as electric vehicles hit the road."

Projected EV Metal Requirements in the year 2000

Aluminum	375,900	2% of total U.S. demand
Cobalt	18,000	89% of total U.S. demand
Copper	150,000	2% of total U.S. demand
Lead	170,000	7% of total U.S. demand
Nickel	334,000	60% of total U.S. demand
Zinc	252,000	11% of total U.S. demand

There are three scenarios of the estimated amounts of EVs used in the U.S.A. for the years 1990 and 2000; low, high, and medium.

	year	number of EVs	% of vehicle population
Lowest scenario	1990	211,000	0.13
	2000	3,000,000	1.7
Highest scenario	1990	965,000	13.7
	2000	24,000,000	13.7
Medium scenario	1990	410,000	
	2000	8,000,000	

The main batteries to be used will be nickel-zinc and nickel-iron units.

A bus will require a 2,547 pound Ni battery pack (nickel-zinc battery);

A passenger car 194 - 236 pounds of nickel and
149-181 pounds of zinc in a nickel-zinc battery;

A passenger car would need 147-176 pounds of nickel in an iron nickel battery. This development would create a signficant dependence on imported nickel unless technical and environmental problems facing the U.S. mining industry are solved in a way that allowed expanded nickel production. Ibid.

P.S.: A serious alternative to the nickel-battery driven EVs is the hydrogen engine,powered by nickel hydrides.These are very stable nickel-compounds-compacted, sintered powder or sponge- which absorb hydrogen under pressure. The hydrogen fuel is finally released by raising the temperature of the nickel-hydride cells.For further information, the reader is advised to consult the pertinent literature. (Courtesy:Dr. Paul Lindon,Director,School of Engineering,Laurentian University).

APPENDIX

TABLES A1 - A9

Table A1

Nickel in Ores, Concentrates, Matte (commodity 255-20)

Year	Quantity (metric tons) Exports	Value ($'000) Exports
1979	42,736	215,771
1978	39,078	162,711
1977	80,548	372,078

Main Customer Countries

Exports	1977	U.K.	51%
		Norway	44%
	1978	Norway	57%
		U.K.	43%
	1979	Norway	63%
		U.K.	37%

Table A2

Nickel in Oxide (commodity 255-30)

Year	Quantity (metric tons) Exports	Value ($'000) Exports
1979	17,190	112,420
1978	27,792	124,061
1977	35,005	158,220

Main Customer Countries

Exports	1977	U.S.	47%
		E.E.C.*	35%
	1978	U.S.	77%
		E.E.C.*	15%
	1979	U.S.	49%
		E.E.C.*	35%

* includes "other countries".

Table A3

Nickel and Nickel Alloy Scrap (commodity 255-40)

Year	Quantity (metric tons) Exports	Value ($'000) Exports
1979	2,382	7,495
1978	2,308	8,023
1977	2,173	6,966

Main Customer Countries

Exports	1977	U.S.	58%
		Italy	23%
	1978	U.S.	85%
		Italy	5%
	1979	U.S.	63%
		Neth.	14%

Table A4

Nickel in Ores, Concentrates and Scrap (commodity 255-99)

Year	Quantity (metric tons) Imports	Value ($'000) Imports
1979	21,176	49,499
1978	31,879	30,952
1977	32,816	57,717

Main Supplying Countries

Imports	1977	Australia	33%
		U.K.	31%
		U.S.	27%
	1978	Australia	52%
		U.K.	31%
		U.S.	15%
	1979	Australia	40%
		U.K.	21%
		U.S.	15%
		France	13%

Table A5

Nickel Anodes Cathodes Ingots Rods (commodity 454-15)

	Quantity (metric tons)			Value ($'000)		
Year	Exports	Imports	Balance	Exports	Imports	Balance
1979	84,706	3,316	81,390	495,040	20,927	474,113
1978	105,666	1,443	104,223	482,797	5,645	477,152
1977	74,631	2,407	72,224	355,633	11,910	343,723

Main Trading Countries

Exports	1977	U.S.	67%	Imports	1977	Norway	87%
		E.E.C.*	24%			U.S.	11%
	1978	U.S.	70%		1978	U.S.	77%
		E.E.C.*	18%			Norway	17%
	1979	U.S.	67%		1979	U.S.	53%
		E.E.C.*	20%			Norway	46%

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* includes "other countries".

Table A6

Nickel Alloy Ingots, Blocks, Rods, Etc. (commodity 454-69)

Year	Quantity (metric tons) Imports	Value ($'000) Imports
1979	1,039	4,624
1978	2,575	6,842
1977	583	3,086

Main Supplying Countries

Imports	1977	U.S.	94%
	1978	Dominican Republic	78%
		U.S.	20%
	1979	U.S.	87%

Table A7

Nickel and Alloy Plate Sheet and Strips (commodity 454-76)

Year	Quantity (metric tons) Imports	Value ($'000) Imports
1979	3,338	26,542
1978	2,751	18,867
1977	2,437	18,298

Main Supplying Countries

Imports	1977	U.S.	86%
		West Germany	14%
	1978	U.S.	82%
		West Germany	16%
	1979	U.S.	62%
		U.K.	26%
		West Germany	11%

Table A8

Nickel and Nickel Alloy Pipe and Tubing (commodity 454-85)

Year	Quantity (metric tons) Imports	Value ($'000) Imports
1979	2,012	27,582
1978	1,546	17,722
1977	1,833	18,418

Main Supplying Countries

Imports	1977	U.S.	78%	1978	U.S.	87%	1979	U.S.	86%
		West Germany	19%		West Germany	11%		West Germany	9%

Table A9

Nickel and Alloy Fabricated Mat. NES (commodity 454-99)

	Quantity (metric tons)			Value ($'000)		
Year	Exports	Imports	Balance	Exports	Imports	Balance
1979	11,850	1,562	10,288	80,540	11,509	69,031
1978	14,854	670	14,184	82,014	5,088	76,926
1977	14,373	701	13,672	81,304	5,301	76,003

Main Trading Countries

Exports	1977	U.S.	85%	Imports	1977	U.S.	64%
		U.K.	6%			West Germany	28%
	1978	U.S.	81%		1978	U.S.	58%
		U.K.	7%			Norway	24%
		S. Africa	5%		1979	U.S.	54%
	1979	U.S.	80%			Philippines	23%
		Neth.	4%			U.K.	17%
		Belg-Lux	4%				